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# MONTHLY NOTICES

OF THE

# ROYAL ASTRONOMICAL SOCIETY.

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VOL. LIV. No. 7. MAY 1894.

## INVITATION OF LADIES TO THE ORDINARY MEETINGS OF THE SOCIETY.

The attention of Fellows is called to the fact that ladies are only admitted to the Evening Meetings of the Society by special invitation of the President, sanctioned by the Council. The invitations are issued at the commencement of each Session.

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VOL. LIV. MAY 11, 1894. No. 7


Captain W. de W. ABNEY, C.B., R.E., D.C.L., F.R.S., President, in the Chair.

Rev. Samuel Robert Browne, M.A., LL.D., Bristol Grammar School, and Camelot, St. John's Road, Clifton, Bristol;
Rev. F. J. Eld, M.A., Whiteladies, Worcester;
Henry Owen, F.R.G.S., F.R.Met.Soc., Royal Thames Yacht Club, 7 Albemarle Street, W.;
George C. Pulsford, Royal Hospital School, Greenwich, S.E.;
W. Rickmer Rickmers, Schwarzspanierstrasse 18, Vienna; and
William Stewart Stewart, Levern House, Barrhead, Scotland,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Major Archibald Drummond, Scots Guards, Guards' Club, Pall Mall, S.W. (proposed by the Earl of Crawford);
S. Maitland Baird Gemmill, care of W. L. Wilson, 254 St. George's Road, Glasgow (proposed by Lord Kelvin); and
Samuel A. Saunder, M.A., Mathematical Master at Wellington College, Berks (proposed by H. F. Newall).

The following were proposed by the Council as Associates of the Society :—

Albert A. Michelson, University of Chicago, U.S.A. ;
H. Poincaré, Paris.

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Seventy-six presents were announced as having been received since the last meeting, including amongst others a series of lantern slides from photographs taken at Sydney Observatory, presented by H. C. Russell.

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*Report of the Joint Solar Eclipse Committee of the Royal Society, the Royal Astronomical Society, and the Solar Physics Committee, for the observation of the Solar Eclipse of* 1893 *April* 16.

(*Communicated by Dr. A. A. Common, Secretary of the Committee.*)

The Committee has done the work which it was constituted to do, and now submits the following Report to the above-mentioned Societies :—

This Committee was formed early in 1892 by the addition to the already constituted Committee of the Royal Astronomical Society of eighteen members nominated by the Royal Society and of eight members nominated by the Solar Physics Committee. Some of the members thus nominated were already members of the old Committee. The original number of the Joint Committee was thirty-two. One new member has been added.

The Committee has to regret the death of two of its members—the Rev. Professor Pritchard, F.R.S., and Mr. H. T. Blandford, F.R.S.

The first meeting of the Committee was held on 1892 May 27, followed by three others on June 17, November 23, and 1893 January 25. At these meetings the work to be undertaken was determined upon and the observers selected; and although a careful estimation of the cost of sending two expeditions (one to Africa and one to Brazil) showed that the amount of money applied for from the Government Grant Fund of the Royal Society was not quite enough, the great advantage that would be gained by two such expeditions so widely separated quite warranted the Committee in sending them.

It was therefore decided to send one expedition to West Africa, under the charge of Dr. Thorpe, and another to Pará Curu, in Northern Brazil, under the charge of Mr. A. Taylor, and that the work done at each station should be of the same

kind. At the African station, however, Dr. Thorpe would undertake, in addition, to make similar observations bearing on the photometric intensity of the coronal light to those he had already made in Grenada in 1886.

The work to be done at each station was :—

1. Photographs of the corona by means of a lens lent by Captain Abney, in continuation of a long series of photographs already obtained at previous eclipses.
2. Photographs of the corona on a larger scale and with a shorter exposure (relatively).
3. Photographs of the surroundings of the Sun, taken by means of a lens with prisms in front.
4. Photographs of the spectrum of the corona with slit spectroscopes.

The work mentioned in the first and second paragraphs above necessitated the construction of a double camera, as it was important to get the two photographs on the different scales taken together. The size of the larger image was about three times that of the smaller. The exposures were arranged so that the longer exposure of the large picture would be comparable with the shorter exposure of the smaller.

Two double tubes were made with dark slides carrying two plates each, and mounted on telescopes lent by the Admiralty.

The work referred to in the third paragraph was undertaken at the suggestion of Mr. Lockyer, who undertook the whole arrangement as to supply of instruments and times of exposure.

The slit spectroscopes in use in Africa were mounted on an equatorial stand lent by the Astronomer Royal. In Brazil the heliostat used for the other spectroscopic work gave the light to fixed spectroscopes.

The Committee were not only very fortunate in getting a sufficient number of observers for the work, but, as events proved, perhaps the very best men that could have been chosen for each class of work.

Dr. Thorpe took charge of the African expedition, and of the work already mentioned to be done by him, and was assisted by Mr. Gray, and also by Mr. Forbes, who went out as a volunteer and at his own cost. The double coronagraph was in charge of Sergeant Kearney, R.E. ; Captain E. H. Hills, R.E., who was also a volunteer and went out at his own expense, had charge of the slit spectroscopes ; and Mr. A. Fowler, of the Royal College of Science, had charge of the prismatic camera. Mr. A. Taylor took charge of the Brazilian expedition, and was assisted by Mr. Shackleton, who had charge of the prismatic camera there, Mr. Taylor using the double coronagraph and the slit spectroscopes. The selected place of observation on the line of totality was in each case on foreign territory. At the request of the Committee the Royal Society made the necessary application,

through the Foreign Office, for permission to land and put up instruments, and for other facilities, to the French and Brazilian Governments ; this in each case was most kindly accorded.

In Africa the point selected as giving the best chance of fine weather was some distance from the coast up the Salum River, and only to be reached by vessel. The Admiralty kindly placed at the disposal of the expedition a gunboat for this service, which met the expedition at Bathurst, took it to the selected spot near Fundium, attended it there, and brought it back to Bathurst when the eclipse was over.

As the return mail-boat from Bathurst did not leave for some time after the return of the expedition there, the Admiralty kindly placed another vessel at the service of the expedition to bring it on to Teneriffe. The eclipse was observed under very favourable circumstances (only a slight haze prevailing), and the results obtained were most successful in every way.

Except for an over-exposure of one of the slit spectroscopes, not in any way due to Mr. Taylor, who had to rely on volunteer assistance in this, the results obtained by the Brazilian expedition were equally successful.

The observers here had to travel much further ; after the voyage to Pernambuco, a coasting voyage to Ceara, and another to Parazinho, with trans-shipment of baggage under considerable difficulties, had to be done. On arrival at Parazinho, the luggage had to be got on shore by native rafts of a very primitive character, and then taken two kilometres up country, to Pará Curu, on bullock waggons. This was accomplished by April 3. The work of getting houses built for the instruments, and the instruments set up and adjusted, was at once begun ; and although continual cloud, combined with heavy rain, very much interfered with the work, the whole of the arrangements were completed before the eclipse, and three days of rehearsals were obtained.

The morning of the eclipse was cloudy, and there seemed very little chance of getting any results ; but everything was arranged to carry on the operations, and the clouds were anxiously watched for a break. Fortunately this break in the clouds came, and the eclipse was observed under excellent conditions.

Mr. Taylor and Mr. Shackleton must have worked in a most praiseworthy way to have got all ready under such very discouraging circumstances, without any such help as could have been given by a gunboat's crew, which almost seems a necessity when instruments have to be landed on practically a barren shore.

Since the return of the expeditions, the Committee has met, on 1893 June 5, and on January 12 and May 2 of this year, to consider the publication of the reports of the various observers, and to arrange for a settlement of the various accounts for expenses incurred.

With regard to publication, the following arrangements have been made :—Dr. Thorpe is preparing and will send to the Royal Society his report on the work he undertook in Africa. Mr.

Lockyer has already sent in to the Royal Society a preliminary report on the results obtained with the prismatic cameras in Africa and Brazil. Captain E. H. Hills has prepared, and the Committee has communicated to the Royal Society, a report on the slit spectroscope photographs obtained in Africa and Brazil.

A report on the corona photographs, taken with the double coronagraph by Mr. Taylor in Brazil and Sergeant Kearney in Africa, with a selection of the photographs for reproduction, and a Paper giving the results of a comparison of the various photographs made by Mr. W. H. Wesley, with a view of detecting any change in the form of the corona, is almost ready, and will be presented to the Royal Astronomical Society for publication, in continuation of similar work already published by this Society.

With regard to the cost of the expeditions, this has considerably exceeded the estimates first made as to the probable cost, particularly in the case of the Brazilian expedition, where, from the nature of the case, the expense has been very heavy. The cost of this expedition was 376*l.* 6*s.* 1*d.*; of the African expedition, 279*l.* 0*s.* 8*d.*; of instruments, plates, and sundries, 157*l.* 5*s.* 7*d.*; making a total of 812*l.* 12*s.* 4*d.*

The original grant of the Royal Society from the Government Grant Fund was 600*l.*; this was supplemented by a further grant of 100*l.*, and the Royal Astronomical Society, on the application of the Committee, gave 112*l.* 12*s.* 4*d.*, thus enabling the Committee to pay all expenses incurred.

The accounts for the money spent have been examined by the auditor appointed by the Committee (General Tennant), and certified correct, and will be sent to the Government Grant Committee in due course.

The recently formed Committee of the Royal Society and the Royal Astronomical Society has kindly undertaken to take charge of the photographs and papers in connection with the 1893 eclipse, and to deal with any question that may arise, which would otherwise come before the Joint Committee.

The members of the Committee, in concluding this Report, wish to put on record their thanks to the Admiralty for the services of H.M.S. *Alecto* and H.M.S. *Blonde* in connection with the African expedition; to the French and Brazilian Governments for the facilities afforded to both expeditions; to the Royal Society, the Royal Astronomical Society, and the Solar Physics Committee, and to the Astronomer Royal, Mr. Lockyer, and Captain Abney for the loans of instruments; to the observers who went to Africa and Brazil, whose names are already mentioned in this Report; and for help in other ways to the following gentlemen amongst others :—R. B. Llewellyn, C.M.G., Administrator at Bathurst; M. Victor Allys, Administrator at Fundium; the Directors of the British and African Steamship Company; the Directors of the Spanish National Submarine Telegraph Company; H.E. the Governor of Ceara; Mr. A. T. G. Williams, H.M.'s Acting Consul at Pernambuco; Mr. G. Holdernesse,

Vice-Consul at Fortaliza; Mr. Reidy, Manager of the Western Brazilian Submarine Telegraph Company; Mr. P. O'Meara, late Chief Engineer of the Port Works, Ceara; M. N. Olsen, Fortaliza, Ceara; Colonel Jas. Brigido, Ceara; and the Directors of the Royal Mail Steamship Company.

1894 *May* 2.

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*Two Questions on Mr. Stone's Proposed Correction to the Measure of Time.* By Professor Simon Newcomb.

From Mr. Stone's note on p. 288 of the *Monthly Notices* for March it would seem that he has not carefully read the short Paper to which his note alludes. This Paper contains no attempt to disprove Mr. Stone's views, nor were any quantities in his theory neglected; on the contrary, the Paper was principally an attempt to apply his theory, as he states it, to the special case of the transit of the Moon observed at Oxford on 1892 January 6, on the supposition that the use of Le Verrier's tables, and the consequent introduction of the new measure of time, commenced in 1892. An inconsistency was found, and Mr. Stone was asked to explain it. He says nothing about this observation, and gives no explanation of the inconsistency. I therefore beg that Mr. Stone will answer these two questions:—

(1) What would have been the tabular error of Hansen's tables of the Moon given by the transit observed at Oxford on 1892 January 6, and printed on p. 4 of the *Monthly Notices* for the present session, if Carlini's tables of the Sun had been continued in use in the *Nautical Almanac* until the present time?

(2) What would have been the tabular error given by the same observation had Carlini's tables been continued until the end of 1891 and Le Verrier's introduced for the first time in 1892?

Either Mr. Stone can answer these very simple questions or he cannot. If he can answer them, I respectfully submit that it is only just to himself that he should do so, giving the numerical computation in each of the two cases fully enough to be understood, comparing it with the actual computation on p. 4, and showing how the result follows from his theory. If he cannot answer them, nothing more need be said.

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*Reply to Professor Newcomb's Two Questions.* By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

Before answering Professor Newcomb's two questions, I feel it necessary to call attention to his statement that in the *Monthly Notices* for March he applied my theory to the special case of the transit of the Moon at Oxford on 1892 January 6, and "without neglecting any quantities in my theory" was led to an inconsistency. Now, this statement is certainly inaccurate. It is simply because Professor Newcomb has neglected certain quantities which, if my views of the physical bases of our time-measures are sound, cannot be neglected without error, that the inconsistency arises; and in my reply I called Professor Newcomb's attention to this point as the real one at issue, but apparently without success.

I now come to Professor Newcomb's questions.

1. "What would have been the tabular error of Hansen's tables of the Moon given by the transit at Oxford on 1892 January 6 if Carlini's tables of the Sun had been continued in use in the *Nautical Almanac* until the present time?"

I understand by this question that the data given in the *Nautical Almanac* are supposed to have been continuously *used for the computation of our "sidereal times at mean noon," and in the actual determinations of our local sidereal times,* and not merely printed without being used. In this case the answer is that the R.A. from Hansen's tables *minus* observed R.A. on 1892 January 6 would have been $= -0^{s}\cdot10$, the result which is given in the *Monthly Notices* for November, and is quoted by Professor Newcomb under the form "Hansen *minus* observed, corrected." I have published the answers to *this and similar questions for all the observations of the Moon made at Oxford since* 1880.

2. The answer to the second question is that the effects produced on $-0^{s}\cdot10$, in the supposed case, would be very small; for they would merely be those due to the difference between the "local sidereal time," which would, if no change had been made, have been accepted by astronomers as 1892 January 1, subject, of course, to any errors of that assumption, and that which would have been accepted as the epoch 1892 January 1, the instant of departure for the new system of time-measures, together with the difference between the sidereal equivalents for the two different intervals of absolute time used as "unit days" before and after the change, multiplied by the number of "unit days" which had elapsed since the change was made, which in the cases supposed would be equal

$$5\times\left[86400^{s}\left(\frac{N+\delta N}{N_0}+\frac{N+\delta N}{2\pi}\right)-86400^{s}\left(\frac{N}{N_0}+\frac{N}{2\pi}\right)\right]$$

$$=5\times86400\,\frac{dN}{N_0}\left(1+\frac{N_0}{2\pi}\right)$$

where $dN$ is the difference between the values of the Sun's mean motion in longitude used in the construction of Le Verrier's and Carlini's solar tables, $N_0$ the Sun's mean motion in the "physical" as distinguished from the "unit day." In the computation of the small corrections it is sufficient to replace $N_0$ by N or $N + \delta N$. The method is, I hope, here explained in sufficient detail for anyone to follow; it is applicable to all such cases, and it is the one which I have used in allowing for the changes in the scales of time-measurement.

Having given distinct answers to Professor Newcomb's two questions, I may perhaps be allowed to explain that the corrections which I have applied in passing from a system of time-measures based on the use of one set of solar tables to those based on the use of a different set of solar tables, are strictly deduced from, and are the necessary mathematical consequences of, the physical bases upon which our measures of time rest. It is the use of two independent systems of time-measures, one based on the geocentric motion of the Sun, the other on the motion of the meridians in right ascension, and the adoption of different, and therefore, at times, erroneous, values of the ratio of a "mean tropical year" to a "mean sidereal day," to transfer "mean solar times" into "sidereal times," and *vice versâ*, which has led to error.

The subject is fully discussed in my paper in the *Monthly Notices*, 1893 December, and need not be repeated here.

But there is one point to which it is perhaps desirable that attention should be called, from the stress which Professor Newcomb lays upon his "table-of-logarithms" argument.

If quantities $\theta^s$ are computed from a definite function $f(t)$ of any variable $t$, in which the "angles" have been expressed in "time" at the rate of 86,400 seconds to an angle $2\pi$, the quantities $\theta^s$ thus obtained for assigned values of the variable $t$ will be identical whenever computed, and if we call the unit in terms of which $t$ is expressed a "mean solar day," the quantities $\theta^s$ computed from the equation

$$\theta^s = f(t)$$

will be identically the same for the same "mean solar time"; but the physical meaning of the variable $t$ is not fixed by any such nomenclature. And although the numerical results will be the same whether the computations were made thirty years ago, are made now, or shall be made thirty years hence, it is *not* true that the *interval of time* which is called a "mean solar day" in practical astronomical work is independent of the conditions between the variable $t$ and the facts of observation by which it is rendered determinate; it is not true that it cannot be changed by alterations of these conditions; it is not true that different errors in our time-determinations will not result from the introduction of different inconsistent conditions between the variable $t$ and the facts of observation from which

our times are found ; and it is not true that the "mean solar day" as thus fixed will be independent of *any use which we may make of the computed quantities* $\theta^s$ *during definite periods* in the actual determination of our "times" from observation. But these assumptions appear to me essential to give any force whatever to such arguments as those brought forward by Professor Newcomb against my views. But instead of these assumptions being true, the length of the *interval of time* which is taken as the "unit day," and called a "mean solar day," in such cases will be absolutely fixed by the conditions introduced between the facts of observation and the variable $t$ by the particular results of observation with which we identify the computed quantities $\theta^s$ to render $t$ determinate ; and the times will be deducible from the equations of condition thus established, either exactly or only approximatively, according as the secular and periodic variations from the mean motion are perfectly or imperfectly allowed for in our theoretical investigations.

In practice we take the quantities $\theta^s$ computed from a definite formula,

$$\theta^s = f(t),$$

or extracted from a selected set of solar tables, and use them as the "local sidereal times at the meridian transits of the Sun" for the corresponding "mean solar times" ; and we find our "local sidereal times" from observation, and therefore the "right ascensions of the Sun from observation," subject to the conditional relation between the local sidereal times and the variable $t$, or the mean solar times, thus established.

The use of a set of solar tables in this way for the determination of the local sidereal times *absolutely* fixes *the particular interval of time which is adopted as the "mean solar day" so long as the same set of solar tables is continuously used.* I have called the "mean solar day" thus fixed a "unit day" to distinguish it from the "physical" or "true" "mean solar day," an interval of time which we cannot change, although we can adopt different units in terms of which to express its length and that of any other intervals of time with which we may be concerned. The "unit day" thus fixed by the adoption and use of a set of solar tables in the construction of which an angle N has been used for the Sun's mean motion in longitude in a "unit day" will contain

$$86400\left(\frac{N}{N_0} + \frac{N}{2\pi}\right) \text{. sidereal seconds;}$$

where $N_0$ denotes the Sun's mean motion in the "physical mean solar day."

The errors made by replacing $N_0$ by the value N, adopted by Carlini, and the value $N + \delta N$, adopted by Le Verrier, cannot both be insensible. And the differences between the terms which

astronomers have neglected, before and after 1864, are such that they account for the *per saltum* change in the errors of Hansen's lunar tables as thus erroneously compared with observation.

If the "mean solar times" were always directly found, as they might be, subject only to errors of observation and of computation of the "equation of time," from the equation

$$\text{Local sidereal times at meridian transits of Sun} = f(t),$$

the change of the scale of time-measurement with the adoption of different solar tables in 1864 would have been directly apparent. To assume otherwise would be to assume that changes in the solar tables adopted for use lead to different "local sidereal times" for the "meridian transits of the Sun." But the change of time-scale is no less real because it has been generally overlooked, and if, whilst finding our local sidereal times, subject to the condition

$$\text{Local sidereal times at meridian transits of Sun} = f(t),$$

we introduce conditional relations between the variable $t$ and the local sidereal times which are inconsistent with this condition, we cannot escape the consequences of these errors on our time-determinations ; and it is these consequences which I have traced.

If Professor Newcomb is prepared to deny that we do *use a set of solar tables to render our local sidereal times observationally determinable*, it is desirable that he should state this. We should in this case be at issue about a matter of fact. But if such is not the case, he must *prove* and not assume that my mathematical deductions are erroneous ; or my results should be accepted.

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*On some possible Improvements in Meridian and Extra-Meridian Observing.* By Professor H. H. Turner, M.A., B.Sc.

1. The very interesting and important Paper by Dr. Gill, printed in the last number of the *Monthly Notices*, will at least have set many astronomers a-thinking.

The final answers to the three questions with which he concludes his paper cannot yet be given ; but he is undeniably in the right in calling for a reconsideration of our astronomical methods—for a report by astronomers upon the organisation of exact astronomy. It is yet to be determined whether an International Congress or Congresses can be assembled successfully to this end. But if this project falls through, there is no reason why an effort should not be made at the present time to set down definitely in print floating ideas on the subjects to which Dr. Gill has referred in his paper ; and if happily the

congresses meet, it will certainly facilitate their labours to have before them in type any definite proposals which may crystallize from discussion.

For this reason I venture to set down one or two small matters which have recently occupied my thoughts at intervals, in the hope that, if valueless in themselves, they may perhaps provoke criticism, comment, or digression which may serve a useful purpose. The theoretical advantages of any new method are apt to shine more brightly before practical trial than after, and are well known to be rapidly dimmed in lustre by the inevitable practical defects which experience reveals. I am therefore conscious that an apology is needed for thus calling attention to methods which are as yet untried; but I hope that Dr. Gill's Paper provides me with something like an excuse.

2. There are probably few who have worked with the transit-circle who have not also speculated on the possibility of avoiding some of its sources of error. Suppose we replace the telescope by a plane mirror, normal to the line of collimation, which is mounted between two carefully made pivots, and can be rotated about a horizontal axis in a manner precisely similar to a transit. And let us observe the image of a star by reflection from this mirror through a telescope *fixed* in the meridian at an arbitrary zenith distance, and pointing to the centre of the mirror; setting the mirror to the position appropriate to the N.P.D. of the star observed. It would seem that by an arrangement of this kind we should secure the following advantages over the simple transit-circle:—

(*a*) The observer might be under cover in a warm room and in comparative comfort; which is a condition of great importance in observing.

(*b*) His position would be the same for all stars; which would eliminate a considerable element of variability in his personal equation.

(*c*) In zenith distance observations many of the refraction difficulties would be avoided. The rays of light from a star to the mirror would not encounter any of the heated strata of air which necessarily occur in a transit-circle room, for the mirror could be in the open. In passing from the mirror to the observer such strata would be encountered, but they would be the same for all stars.

(*d*) The effect of flexure in a reflecting surface is much greater than (say) in an object-glass. But by making the mirror thick enough relatively to its aperture flexure may be reduced to insensible dimensions, and the instrument would then compare favourably with the ordinary transit-circle with its long tube, which is very liable to flexure.

(*e*) To develop advantage (*a*) to its full extent, the observer must be able to make all the necessary observations without moving from his seat at the telescope, including circle readings, and readings of the barometer and thermometers. There would

not seem to be any serious practical difficulty in arranging this, much in the same way as the numerous readings are made from the eye-end of a modern equatorial.

(*f*) The angle of incidence of the light of a star on the mirror is only small for a limited range in zenith distance so long as we use the same fixed telescope. But several fixed telescopes at different zenith distances might be used, and the results would very usefully check one another. Or the same telescope might be fixed in different positions from time to time, without disturbing the adjustments of the movable parts of the instrument—viz. the revolving mirror.

3. With the slight addition of a fixed telescope *not* in the meridian the *same mirror* can be converted into an extra-meridional instrument. Such a telescope will command, as the mirror revolves, a small circle of the sky whose pole is the east or west point, and whose angular radius is the inclination of the telescope to the west or east direction. The errors of adjustment of the revolving mirror may be determined by the meridian observations, the fixed telescope only introducing two additional constants—say its altitude and azimuth. This combination of telescope and mirror corresponds to a transit-circle whose telescope is inclined to the horizontal axis, and describes a cone instead of the meridian. The hour angle at which a body crosses the small circle commanded by such an instrument is independent of the latitude, and depends only on the declination of the object and the inclination of the telescope to the horizontal axis. The latitude of course affects the circle reading at transit; but there is an obvious advantage in not having the latitude enter into both co-ordinates, as in the case of the altazimuth.

4. Once the revolving mirror is set up, it may in fact be used to reflect into a regular battery of fixed telescopes. The project sounds an extravagant one, but these telescopes need not be large—say, 4 inches aperture—and much may be done with a single telescope placed in various positions if its co-ordinates be carefully determined on each occasion of shifting. A pair of telescopes, one of which was left untouched during the removal of the other, would give a virtually continuous series of observations.

5. Circles are now so admirably graduated that perhaps the circle is the part of a meridian instrument least in need of improvement. But the labour of determining division errors, and the risk of systematic error even after a careful determination, are responsible for the following crude suggestion. Returning to the mirror of paragraph 2, suppose a hoop whose centre is on the horizontal axis to be rotated by clock-work, and a mark on its inner surface to be reflected by the mirror into the field of view of a small telescope, fixed near the transit telescope; the rotation of the hoop would cause the image of the mark gradually to cross the field of view and disappear. But a second mark might be added which would appear as the first disappeared; and a

third again, and so on ; so that, in whatever position the mirror was placed, some mark on the hoop (which could be otherwise identified) would be crossing the field of view of the small telescope. Then the position of the mirror would be determined by the time of transit of the particular mark. The intervals of marks round the hoop would be determined by transits at leisure. Some accidental errors would doubtless be introduced by this method ; but the great safeguard against systematic error would be that the zero point would be different on each night, depending simply on the moment of starting the clock-work which rotates the hoop.

6. Concerning the clock, which would become of vital importance in both co-ordinates, if any idea such as that in paragraph 5 were carried into practice, the time would seem to have arrived when observatories of the first class should have not one standard clock, but a number, all kept at a nearly constant temperature, and isolated as far as possible from each other. Here, again, it is far easier to make a suggestion than find the necessary funds to carry it out. The idea of Professor Mendenhall and others, that a free pendulum should be used as an ultimate standard of reference as far as possible, is also well worthy of consideration.

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*The Effect of Personality in Observations of the Sun's Right Ascension on the Determination of the Position of the Ecliptic.* By F. W. Dyson and W. G. Thackeray.

(*Communicated by the Astronomer Royal.*)

In the introduction to the Five-Year Greenwich Catalogue of Fundamental Stars, shortly to be published, it is shown that the observations of the Sun for the years 1887–1891 indicate a correction of $+^{s}\cdot043$ to the adopted right ascensions of the clock-stars used in those years. It was considered advisable not to apply so large a correction to the right ascensions, and the Five-Year Catalogue is therefore referred to the epoch of the standard right ascensions of the Ten-Year Catalogue of 1880. Since then it appears, from the discussion of the position of the ecliptic for 1892 and 1893, that this large correction is more than confirmed, and if no cause can be assigned for it, then, following the precedent of previous years, a large correction to the right ascensions of all stars will be required in the next Greenwich Catalogue.

As the instrument, tables, and method of reduction are the same, and the only element of change in connection with the observations is the observing staff, it seems reasonable to infer a probable cause in the change in the *personnel* of the observers. It is well known that observers have large personal equations in measuring both the horizontal and vertical diameters of the Sun with the

transit-circle. But it does not seem to be equally well recognised that distinct and well-marked personalities appear in the right ascension of the Sun's centre, deduced from observations of the two limbs. Nor are the serious discordances which may arise from this cause in the values of the correction to the equinox sufficiently appreciated.

The observations of R.A. are reduced with each observer's own clock-error ; or in those few cases where the observer himself has not been able to obtain a clock-error, the clock-error with which the observation is reduced is always first corrected for difference in the stellar personal equations, so that the error we are considering arises from the difference of personal equation in taking observations of the Sun and stars.

The R.A.'s and N.P.D.'s deduced from the observation are compared with the tabular places given in the *Nautical Almanac*, which since 1864 have been computed from Le Verrier's tables. The differences are given in the annual volumes of Greenwich *Observations* as apparent tabular error. These quantities are grouped in months, and the error of ecliptic N.P.D. obtained by means of Sir G. B. Airy's P.Q.R.S. tables. On the assumption that these errors can be represented by an equation of the form

$$x \cos l + y \sin l + z,$$

when $l$ is the Sun's longitude, twelve equations are formed, which, solved by the method of least squares, give the apparent tabular errors in the position of the equinox, obliquity of the ecliptic, and adopted colatitude.

It will be convenient to point out the exact effect of errors in the right ascension and declination on $x$, $y$, and $z$. The error in ecliptic N.P.D. = R × error in R.A. + S × error in N.P.D. S only varies between + 1 and + 0·9 ; but R has a considerable range, being equal to 15 sin $\epsilon$ cos $l$, where $\epsilon$ is the obliquity of the ecliptic.

Denoting by

$e^s$ the observed error in R.A.

$f''$ „ „ N.P.D.

and

$n$ the number of observations,

there are $n$ equations determining $x$, $y$, $z$, of the form

$$x \cos l + y \sin l + z = 15\, e \sin \epsilon \cos l + \mathrm{S}f.$$

The normal equations are

$$x\Sigma \cos^2 l + y\Sigma \sin l \cos l + z\Sigma \cos l = 15 \sin \epsilon \Sigma e \cos^2 l + \Sigma \mathrm{S}f \cos l,$$

$$x\Sigma \sin l \cos l + y\Sigma \sin^2 l + z\Sigma \sin l = 15 \sin \epsilon \Sigma e \sin l \cos l + \Sigma \mathrm{S}f \sin l,$$

$$x\Sigma \cos l + y\Sigma \sin l + z \,.\, n = 15 \sin \epsilon \Sigma e \cos l + \Sigma \mathrm{S}f.$$

If the $n$ observations are distributed fairly evenly throughout the year

$$\Sigma \sin 2l, \Sigma \cos 2l, \Sigma \sin l, \Sigma \cos l \text{ all} = 0.$$

$$\Sigma \sin^2 l = \Sigma \left(\tfrac{1}{2} - \tfrac{1}{2} \cos 2l\right) = \frac{n}{2}$$

$$\Sigma \cos^2 l = \Sigma \left(\tfrac{1}{2} + \tfrac{1}{2} \cos 2l\right) = \frac{n}{2}.$$

Therefore the normal equations are

$$\left.\begin{aligned} \frac{n}{2}x &= 15 \sin \epsilon \Sigma e \cos^2 l + \Sigma S f \cos l \\ \frac{n}{2}y &= 15 \sin \epsilon \,.\, \Sigma e \sin l \cos l + \Sigma S f \sin l \\ nz &= 15 \sin \epsilon \Sigma e \cos l + \Sigma S f. \end{aligned}\right\}$$

These equations show

1. That a constant systematic error $e$ will produce

($\alpha$) in $x$ the error

$$\frac{2}{n} \,.\, 15 \sin \epsilon \, e\Sigma \cos^2 l, \textit{ i.e. } e\, 15 \sin \epsilon,$$

or directly affects the position of the equinox ;

($\beta$) in $y$ the error

$$\frac{2}{n} 15 \sin \epsilon \,.\, e\Sigma \sin l \cos l, \textit{ i.e.} = 0;$$

($\gamma$) in $z$ the error

$$\frac{1}{n} \,.\, 15 \sin \epsilon \, e\Sigma \cos l, \textit{ i.e.} = 0.$$

2. An error in $f$ systematically of one sign in the first half of the year and the opposite in the second half of the year has an important effect on $x$, none on $y$ or $z$. An error in $f$ systematically of one sign in the summer and the opposite in the winter would have an important effect on $y$, but none on $x$ and $z$.

An error in $f$ of the same sign throughout the year has an important effect on $z$, but none on $x$ and $y$.

Therefore any personality ($e$) an observer has in taking the right ascension of the Sun gives an error $15 \sin \epsilon \,.\, e$ in the value of $x$, and therefore an error $e$ in the absolute right ascensions of all the clock-stars. An error of the nature of Chandler's latitude variation, having a period of fourteen months, which is not far removed from an annual period, would have an important effect on $x$ or $y$ according as its maximum and minimum values were near the equinoxes or the solstices. Thus Chandler's variation of the latitude will in some years affect the value of $x$ and in other years the value of $y$ to the extent of $^{s}\cdot 050$.

In the present paper we propose to confine ourselves chiefly to the effect of personality in observing right ascensions of the Sun, as the N.P.D.'s of the Sun before 1878 are not immediately available for this purpose, requiring considerable systematic corrections to make them comparable with the observations made since. The introduction of Le Verrier's tables in 1864 into the *Nautical Almanac* computations of the Sun's place will afford a proper date for the period from which to begin, as far as the Greenwich observations are concerned. As a check on our deductions, and as affording valuable additional data, we have also discussed the Washington observations since 1872 up to 1887, during which period Professor Eastman has continuously observed.

The daily observations of the Sun are exhibited both in the Greenwich and Washington publications in the planetary sections, in the former as tabular errors, in the latter as corrections to the ephemeris. From these sections the various quantities thus given are taken and tabulated under the various observers' initials, and the yearly mean then taken, only those observations being used in which both limbs were observed. In the case of the Greenwich observations, we have grouped under the heading "Miscellaneous" all observers other than the regular observing assistants, as the number of observations of any one was too few, and the period during which he observed too short, for the accurate determination of his personal equation.

TABLE I.

*Greenwich Mean Tabular Errors of R.A. of Sun (from mean of both limbs).*

| | D. | | E. | | C. | | J. C. | | | Miscellaneous. | | Mean. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | s | No. of Obs. | s | No. of Obs. | s | No. of Obs. | s | No. of Obs. | | s | No. of Obs. | s | No. of Obs. |
| 1864 | +·019 | 14 | −·012 | 23 | +·010 | 26 | −·067 | 18 | ... | +·074 | 23 | +·007 | 104 |
| 1865 | −·010 | 14 | +·015 | 22 | +·061 | 23 | −·037 | 16 | ... | +·039 | 25 | +·020 | 100 |
| 1866 | −·022 | 13 | −·060 | 20 | −·007 | 16 | −·064 | 17 | ... | +·054 | 28 | −·012 | 94 |
| 1867 | −·020 | 12 | −·087 | 17 | +·057 | 11 | −·068 | 13 | ... | −·005 | 20 | −·026 | 73 |
| 1868 | +·006 | 8 | −·065 | 19 | +·020 | 24 | +·009 | 15 | ... | +·063 | 36 | +·016 | 102 |
| 1869 | +·033 | 12 | −·012 | 17 | +·033 | 13 | −·032 | 13 | ... | +·043 | 21 | +·015 | 76 |
| | L. | | | | | | | | | | | | |
| 1870 | +·019 | 13 | −·032 | 18 | +·037 | 20 | −·040 | 21 | ... | +·053 | 32 | +·012 | 104 |
| 1871 | +·030 | 22 | −·009 | 14 | +·032 | 14 | −·084 | 14 | ... | +·096 | 36 | +·033 | 100 |
| 1872 | +·065 | 22 | −·058 | 21 | +·001 | 22 | −·079 | 16 | ... | +·026 | 36 | −·001 | 117 |
| | | | | | | | A. D. | | | | | | |
| 1873 | +·056 | 19 | −·028 | 17 | +·025 | 17 | +·059 | 23 | ... | +·056 | 26 | +·037 | 102 |
| 1874 | +·081 | 19 | −·015 | 11 | +·036 | 18 | +·111 | 17 | ... | +·035 | 28 | +·053 | 93 |
| | | | T. | | | | | | | | | | |
| 1875 | +·081 | 14 | ·000 | 13 | +·026 | 13 | +·048 | 14 | ... | +·075 | 41 | +·055 | 95 |
| 1876 | +·095 | 10 | +·004 | 20 | +·035 | 13 | +·044 | 22 | ... | +·080 | 34 | +·052 | 99 |
| 1877 | +·030 | 6 | +·005 | 13 | +·053 | 13 | +·031 | 15 | ... | +·070 | 28 | +·045 | 75 |
| 1878 | ... | | +·052 | 11 | +·024 | 14 | +·018 | 14 | ... | +·069 | 37 | +·049 | 76 |
| 1879 | ... | | +·038 | 9 | +·005 | 12 | +·022 | 12 | ... | +·090 | 26 | +·051 | 59 |
| 1880 | ... | | +·046 | 19 | +·010 | 16 | +·007 | 24 | ... | +·105 | 39 | +·054 | 98 |

| | T. L. | | T. | | C. | | A. D. | | | | Miscellaneous. | | Mean. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | s | No. of Obs. | s | No. of Obs. | s | No. of Obs. | s | No. of Obs. | | | s | No. of Obs. | s | No. of Obs. |
| 1881 | +·071 | 26 | +·028 | 16 | +·011 | 15 | +·030 | 21 | ... | | +·062 | 29 | +·046 | 107 |
| | | | | | H. | | | | | | | | | |
| 1882 | +·077 | 18 | +·022 | 19 | +·030 | 20 | +·007 | 13 | ... | | +·074 | 18 | +·044 | 88 |
| 1883 | +·085 | 19 | −·014 | 23 | +·025 | 17 | +·033 | 20 | ... | | +·085 | 34 | +·046 | 113 |
| 1884 | +·081 | 20 | +·009 | 15 | +·014 | 15 | +·003 | 11 | ... | | +·099 | 38 | +·055 | 99 |
| 1885 | +·052 | 20 | +·009 | 16 | +·028 | 25 | +·004 | 16 | ... | | +·072 | 38 | +·041 | 115 |
| 1886 | +·081 | 16 | +·021 | 11 | +·015 | 24 | +·042 | 18 | ... | | +·105 | 46 | +·065 | 115 |
| 1887 | +·086 | 17 | +·018 | 17 | +·007 | 21 | +·025 | 19 | ... | | +·084 | 51 | +·053 | 125 |
| 1888 | +·071 | 13 | +·004 | 13 | +·034 | 14 | +·046 | 17 | ... | | +·051 | 30 | +·043 | 87 |
| 1889 | +·087 | 14 | +·023 | 12 | +·031 | 19 | +·065 | 19 | ... | | +·085 | 43 | +·065 | 107 |
| 1890 | +·054 | 23 | +·069 | 11 | −·023 | 28 | +·040 | 22 | ... | | +·081 | 45 | +·046 | 129 |
| | | | | | | | | | A. C. | | | | | |
| | | | | | | | | | s | No. of Obs. | | | | |
| 1891 | +·079 | 15 | +·051 | 12 | +·030 | 21 | +·090 | 9 | +·073 | 16 | +·092 | 43 | +·072 | 116 |
| | | | B. | | | | T. H. | | | | | | | |
| 1892 | +·072 | 19 | +·104 | 22 | −·001 | 9 | +·064 | 15 | +·067 | 31 | +·103 | 40 | +·080 | 136 |
| 1893 | +·047 | 9 | +·137 | 28 | +·007 | 29 | +·104 | 11 | +·068 | 27 | +·120 | 63 | +·090 | 167 |

The initials D., E., C., J. C., L., A. D., T., T. L., H., A. C., B., and T. H., are those of Messrs. Dunkin, Ellis, Criswick, James Carpenter, Lynn, Downing, Thackeray, Lewis, Hollis, Crommelin, Bryant, and Hudson.

The heading "Miscellaneous" includes all observations other than those of the assistants observing regularly throughout the year.

In the accompanying tables we have adopted exactly the same method as Mr. Dunkin in his Paper on "Personality" in *Monthly Notices*, 35 (2). For Greenwich we have adopted C. (Mr. Criswick) as our standard, and when he ceased to observe in 1882 we have referred back to him through

$$\frac{\text{A. D.} + \text{T.}}{2},$$

and have thus assumed that A. D. and T. have kept the same personality; this assumption is confirmed by the fact that the difference of personal equation for A. D. and T. was $+^{s}\cdot017$ before and $+^{s}\cdot018$ after 1881; and after A. D. and T. ceased observing in 1891 through

$$\frac{\text{H.} + \text{T. L.}}{2}.$$

To connect the period after 1881, when C. ceased to observe, with the following years, we have taken A. D. and T. as our deputy standard, and have taken

$$\frac{\text{A. D.} + \text{T.}}{2} - \text{C.} = +0^{s}\cdot008.$$

Secondly, to connect A. C., B., and T. H. with C., we have referred them to

$$\frac{\text{T. L.} + \text{H.}}{2},$$

and have taken

$$\frac{\text{T. L.} + \text{H.}}{2} - \text{C.} = +0^{s}\cdot027.$$

For Washington we have adopted as our standard (Professor Eastman) E., as he has observed continuously throughout the period. In both cases we have adopted the same principles. We have considered it best to assume that variations in the annual means of an observer's tabular errors is either accidental or due to causes which would also similarly affect other observers; therefore we do not attempt to fix any arbitrary periods as to when an observer did or did not change his habit of observing, but we take our standard observer, or his *locum tenens*, and find the mean of his observations, and of any other observer we wish to compare with him, for the period during which they were observing conjointly, and the difference between these results gives us the correction to be applied to the other observer to reduce to the standard. We have, however, divided the group headed "Miscellaneous" into two groups, one conterminous with the observing life of C., and the second with that of A. D. and T. There is some change in the two corrections due, probably, to the larger number of young observers in the latter years.

TABLE II.

*Corrections to reduce Tabular R.A.'s of Sun to C. as Standard.*

| Observer. | Period. | Corr. | Observer. | Period. | Corr. |
|---|---|---|---|---|---|
| | | s | | | s |
| D.—C. | 1864-69 | +0·025 | T. L.—C. | 1881-93 | −0·055 |
| E.—C. | 1864-74 | +0·060 | H.—C. | 1882-93 | +0·001 |
| J. C.—C. | 1864-72 | +0·078 | A. C.—C. | 1891-93 | −0·054 |
| L.—C. | 1870-77 | −0·026 | B.—C. | 1892-93 | −0·117 |
| A. D.—C. | 1873-81 | −0·016 | T. H.—C. | 1892-93 | −0·075 |
| T.—C. | 1875-81 | 0·000 | Misc.—C. | 1882-93 | −0·065 |
| Misc.—C. | 1864-81 | −0·036 | | | |

The following table contains the results of Table I. corrected by the quantities in Table II. explained as above.

## Table III.

*Tabular Errors of R.A. of Sun (from mean of both limbs) corrected to C.*

| | D. | | E. | | C. | | J. C. | | | Miscellaneous. | | Mean of Assistants. | Mean of all. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | s | No. of Obs. | s | No. of Obs. | s | No. of Obs. | s | No. of Obs. | | s | No. of Obs. | s | s |
| 1864 | +·044 | 14 | +·048 | 23 | +·010 | 26 | +·011 | 18 | ... | +0·38 | 23 | +·028 | +·030 |
| 1865 | +·015 | 14 | +·075 | 22 | +·061 | 23 | +·041 | 16 | ... | +·003 | 25 | +·052 | +·040 |
| 1866 | +·003 | 13 | ·000 | 20 | −·007 | 16 | +·014 | 17 | ... | +·018 | 28 | +·003 | +·008 |
| 1867 | +·005 | 12 | −·027 | 17 | +·057 | 11 | +·010 | 13 | ... | −·041 | 20 | +·007 | −·006 |
| 1868 | +·031 | 8 | −·005 | 19 | +·020 | 24 | +·087 | 15 | ... | +·027 | 36 | +·028 | +·028 |
| 1869 | +·058 | 12 | +·048 | 17 | +·033 | 13 | +·046 | 13 | ... | +·007 | 21 | +·047 | +·036 |
| | L. | | | | | | | | | | | | |
| 1870 | −·007 | 13 | +·028 | 18 | +·037 | 20 | +·048 | 21 | ... | +·017 | 32 | +·030 | +·026 |
| 1871 | +·004 | 22 | +·051 | 14 | +·032 | 14 | −·006 | 14 | ... | +·060 | 36 | +·020 | +·034 |
| 1872 | +·039 | 22 | +·002 | 21 | +·001 | 22 | −·001 | 16 | ... | −·010 | 36 | +·011 | +·005 |
| | | | | | | | A. D. | | | | | | |
| 1873 | +·030 | 19 | +·032 | 17 | +·025 | 17 | +·043 | 23 | ... | +·020 | 26 | +·033 | +·030 |
| 1874 | +·055 | 19 | +·045 | 11 | +·036 | 18 | +·095 | 17 | ... | −·001 | 28 | +·058 | +·040 |
| | | | T. | | | | | | | | | | |
| 1875 | +·055 | 14 | ·000 | 13 | +·026 | 13 | +·032 | 14 | ... | +·039 | 41 | +·029 | +·033 |
| 1876 | +·071 | 10 | +·004 | 20 | +·035 | 13 | +·028 | 22 | ... | +·044 | 34 | +·029 | +·037 |
| 1877 | +·004 | 6 | +·005 | 13 | +·053 | 13 | +·015 | 15 | ... | +·034 | 28 | +·022 | +·026 |
| 1878 | ... | | +·052 | 11 | +·024 | 14 | +·002 | 14 | ... | +·033 | 37 | +·026 | +·030 |
| 1879 | ... | | +·038 | 9 | +·005 | 12 | +·006 | 12 | ... | +·054 | 26 | +·016 | +·032 |
| 1880 | ... | | +·046 | 19 | +·010 | 16 | −·009 | 24 | ... | +·069 | 39 | +·014 | +·038 |

| | T. L. | | T. | | [C. | | A. D. | | | Miscellaneous. | | Mean of Assistants. | Mean of all. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | s | No. of Obs. | s | No. of Obs. | s | No. of Obs. | s | No. of Obs. | | s | No. of Obs. | s | s |
| 1881 | +·016 | 26 | +·028 | 16 | +·011 | 15 | +·014 | 21 | ... | +·026 | 29 | +·017 | +·021 |
| | | | | | H. | | | | | | | | |
| 1882 | +·022 | 18 | +·020 | 19 | +·031 | 20 | −·009 | 13 | ... | +·009 | 18 | +·020 | +·018 |
| 1883 | +·030 | 19 | −·014 | 23 | +·026 | 17 | +·017 | 20 | ... | +·020 | 34 | +·013 | +·015 |
| 1884 | +·026 | 20 | +·009 | 15 | +·015 | 15 | −·013 | 11 | ... | +·034 | 38 | +·012 | +·021 |
| 1885 | −·003 | 20 | +·009 | 16 | +·029 | 25 | −·012 | 16 | ... | +·007 | 38 | +·006 | +·006 |
| 1886 | +·026 | 16 | +·021 | 11 | +·016 | 24 | +·026 | 18 | ... | +·040 | 46 | +·023 | +·030 |
| 1887 | +·031 | 17 | +·018 | 17 | +·008 | 21 | +·009 | 19 | ... | +·019 | 51 | +·016 | +·017 |
| 1888 | +·016 | 13 | +·004 | 13 | +·035 | 14 | +·030 | 17 | ... | −·014 | 30 | +·021 | +·009 |
| 1889 | +·032 | 14 | +·023 | 12 | +·032 | 19 | +·049 | 19 | ... | +·020 | 43 | +·034 | +·028 |
| 1890 | −·001 | 23 | +·069 | 11 | −·022 | 28 | +·024 | 22 | ... | +·016 | 45 | +·008 | +·011 |
| | | | | | | | | | A. C. | | | | |
| | | | | | | | | | s No of Obs. | | | | |
| 1891 | +·024 | 15 | +·051 | 12 | +·031 | 21 | +·074 | 9 | +·019 16 | +·027 | 43 | +·033 | +·031 |
| | | | B. | | | | T. H. | | | | | | |
| 1892 | +·017 | 19 | −·013 | 22 | ·000 | 9 | −·011 | 15 | +·013 31 | +·038 | 40 | +·003 | +·013 |
| 1893 | −·008 | 9 | +·020 | 28 | +·008 | 29 | +·029 | 11 | +·014 27 | +·055 | 63 | +·013 | +·029 |
| | | | | | | | | | Mean ... ... ... | | | +·022 | |

Tables IV., V., and VI. are in every way similar to tables I., II., and III., only referred to the Washington observations.

TABLE IV.

*Washington Observations.—Corrections to Tabular R.A.'s of Sun from the American Ephemeris.*

| | E. | | Hn. | | Sk. | | F. | | S. | | Mean. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | s | No. of Obs. | s | No. of Obs. | s | No. of Obs. | s | No. of Obs. | s | No. of Obs. | s | No. of Obs. |
| 1872 | −·069 | 36 | ... | | ... | | +·028 | 25 | +·008 | 20 | −·020 | 81 |
| 1873 | −·001 | 24 | +·023 | 8 | +·010 | 3 | +·013 | 18 | −·018 | 8 | +·004 | 62 |
| 1874 | −·042 | 25 | ... | | +·116 | 23 | +·094 | 14 | −·033 | 16 | +·031 | 78 |
| | | | P. | | | | | | | | | |
| 1875 | +·006 | 25 | +·039 | 16 | +·042 | 26 | +·030 | 24 | +·117 | 3 | +·031 | 94 |
| 1876 | −·025 | 24 | −·051 | 27 | −·003 | 22 | +·098 | 20 | ... | | −·001 | 93 |
| 1877 | −·012 | 14 | −·039 | 12 | +·021 | 15 | +·102 | 10 | ... | | +·014 | 51 |
| | | | | | | | | | Pr. | | | |
| 1878 | −·035 | 10 | −·057 | 11 | +·013 | 17 | +·043 | 12 | −·011 | 7 | −·006 | 57 |
| 1879 | −·030 | 1 | +·013 | 7 | +·030 | 19 | +·096 | 19 | +·081 | 24 | +·063 | 70 |
| | | | | | | | R. | | W. | | | |
| 1880 | −·029 | 12 | −·026 | 7 | +·021 | 16 | +·008 | 10 | +·010 | 16 | +·001 | 61 |
| 1881 | −·046 | 15 | ... | | +·027 | 12 | +·003 | 29 | +·027 | 22 | +·004 | 78 |
| 1882 | −·049 | 13 | ... | | +·047 | 13 | −·044 | 16 | +·014 | 35 | −·003 | 77 |
| 1883 | −·028 | 19 | −·043 | 3 | +·041 | 17 | −·076 | 16 | +·008 | 11 | −·017 | 66 |
| 1884 | −·037 | 26 | −·032 | 24 | +·042 | 22 | ... | | +·025 | 26 | −·002 | 98 |
| 1885 | −·032 | 20 | −·027 | 12 | −·003 | 19 | ... | | −·003 | 29 | −·014 | 80 |
| 1886 | −·024 | 22 | +·001 | 15 | +·006 | 23 | ... | | +·042 | 18 | +·005 | 78 |
| 1887 | −·046 | 14 | −·027 | 17 | +·014 | 27 | ... | | +·028 | 20 | −·002 | 78 |

The initials E., Hn., Sk., F., S., P., Pr., R., and W. refer to Professors Eastman and Holden, Messrs. Skinner, Frisby, Stone, Paul, Pritchett, Rock, and Winlock.

TABLE V.

*Corrections to reduce Tabular Corrections of R.A. of Sun to E. as standard.*

| | s | | s |
|---|---|---|---|
| Hn.—E. = | −·024 | Sk.—E. = | −·064 |
| P.—E. = | −·001 | Pr.—E. = | −·096 |
| S.—E. = | −·028 | R.—E. = | −·012 |
| F.—E. = | −·085 | W.—E. = | −·056 |

TABLE VI.

*Washington Observations.—Corrections to Tabular R.A.'s of Sun from the American Ephemeris (corrected to E.).*

| | E. | | Hn. | | Sk. | | F. | | S. | | Mean. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | s | No. of Obs. | s | No. of Obs. | s | No. of Obs. | s | No. of Obs. | s | No. of Obs. | s |
| 1872 | −·069 | 36 | ... | | ... | | −·057 | 25 | −·020 | 20 | −·052 |
| 1873 | −·001 | 24 | −·001 | 8 | −·054 | 3 | −·072 | 18 | −·046 | 8 | −·030 |
| 1874 | −·042 | 25 | ... | | +·052 | 23 | +·009 | 14 | −·061 | 16 | −·009 |
| 1875 | +·006 | 25 | +·038 P. | 16 | −·022 | 26 | −·055 | 24 | +·089 | 3 | −·009 |
| 1876 | −·025 | 24 | −·052 | 27 | −·067 | 22 | +·013 | 20 | ... | | −·033 |
| 1877 | −·012 | 14 | −·042 | 12 | −·043 | 15 | +·017 | 10 | ... | | −·022 |
| 1878 | −·035 | 10 | −·058 | 11 | −·051 | 17 | −·042 | 12 | −·107 Pr. | 7 | −·055 |
| 1879 | −·030 | 1 | +·012 | 7 | −·034 | 19 | +·011 | 19 | −·015 | 24 | −·011 |
| 1880 | −·029 | 12 | −·027 | 7 | −·043 | 16 | −·004 R. | 10 | −·049 W. | 16 | −·033 |
| 1881 | −·046 | 15 | ... | | −·037 | 12 | −·009 | 29 | −·029 | 22 | −·026 |
| 1882 | −·049 | 13 | ... | | −·017 | 13 | −·056 | 16 | −·042 | 35 | −·042 |
| 1883 | −·028 | 19 | −·044 | 3 | −·023 | 17 | −·088 | 16 | −·048 | 11 | −·045 |
| 1884 | −·037 | 26 | −·033 | 24 | −·022 | 22 | ... | | −·031 | 26 | −·030 |
| 1885 | −·032 | 20 | −·028 | 12 | −·067 | 19 | ... | | −·059 | 29 | −·050 |
| 1886 | −·024 | 22 | ·000 | 15 | −·058 | 23 | ... | | −·014 | 18 | −·023 |
| 1887 | −·046 | 14 | −·028 | 17 | −·050 | 27 | ... | | −·028 | 20 | −·038 |

The following table (VII.) contains the mean annual error of R.A. which was used in the discussions of the positions of the ecliptic for the various Greenwich Catalogues. The third column contains the annual mean error of R.A. of all the observations reduced to C. as a standard from Table III. Column 4 contains the corrections which have been or will be applied in the Greenwich Catalogues to the right ascensions of all stars. As a systematic error $e$ was shown in the beginning of this Paper to affect the correction to the equinox directly, column 2 — column 1 is the correction required to column 3 to deduce the correction to the equinox corresponding to the R.A.'s of the Sun referred to C.

TABLE VII.

| Year. | Annual Mean Error of R.A. (1) | Annual Mean Error of R.A. corrected to C. | Correction to Equinox. (3) | (3) corrected by (2−1). |
|---|---|---|---|---|
| | s | s | s | s |
| 1864 | + 0·002 | + 0·030 | − 0·002 | + 0·026 |
| 1865 | + ·015 | + ·040 | − ·010 | + ·015 |
| 1866 | − ·013 | + ·008 | − ·006 | + ·015 |
| 1867 | − ·013 | − ·006 | − ·051 | − ·044 |
| 1868 | − ·005 | + ·028 | − ·058 | − ·025 |
| 1869 | + ·006 | + ·036 | − ·001 | + ·029 |
| 1870 | + ·007 | + ·026 | − ·012 | + ·007 |
| 1871 | + ·020 | + ·034 | + ·044 | + ·058 |
| 1872 | + ·002 | + ·005 | − ·019 | − ·016 |
| 1873 | + ·036 | + ·030 | + ·058 | + ·052 |
| 1874 | + ·051 | + ·040 | − ·049 | − ·060 |
| 1875 | + ·054 | + ·033 | + ·038 | + ·017 |
| 1876 | + ·044 | + ·037 | + ·055 | + ·048 |
| 1877 | + ·030 | + ·026 | + ·044 | + ·040 |
| 1878 | + ·050 | + ·030 | − ·049 | − ·069 |
| 1879 | + ·043 | + ·032 | + ·025 | + ·014 |
| 1880 | + ·060 | + ·038 | − ·092 | − ·114 |
| 1881 | + ·049 | + ·021 | − ·035 | − ·063 |
| 1882 | + ·036 | + ·018 | − ·027 | − ·045 |
| 1883 | + ·045 | + ·015 | − ·002 | − ·032 |
| 1884 | + ·056 | + ·021 | + ·084 | + ·049 |
| 1885 | + ·051 | + ·006 | − ·009 | − ·054 |
| 1886 | + ·066 | + ·030 | + ·094 | + ·058 |
| 1887 | + ·051 | + ·017 | − ·046 | − ·080 |
| 1888 | + ·042 | + ·009 | + ·072 | + ·039 |
| 1889 | + ·064 | + ·028 | + ·024 | − ·012 |
| 1890 | + ·047 | + ·011 | + ·093 | + ·057 |
| 1891 | + ·070 | + ·031 | + ·088 | + ·049 |
| 1892 | + ·078 | + ·013 | + ·040 | − ·025 |
| 1893 | + ·086 | + ·029 | + ·090 | + ·033 |

These new values, while showing more accordance, are only roughly corrected, as of course, properly speaking, each observation should be corrected for personality before the monthly means are formed.

From 1887–91 the correction to the equinox is now + $^{s}$·011 instead of + $^{s}$·043, but the correction to the Ten-Year Catalogue, 1880, is now − $^{s}$·025 instead of + $^{s}$·003. This result is doubtless

due partly to the roughness of the method of correction, and partly to the existence of periodic errors in the N.P.D.'s, pointed out above.

From 1864–69 the right ascensions of the stars depend on the equinox of the 1860 Catalogue, from 1870–77 on that of the 1864 Catalogue, from 1878–88 on that of the 1872 Catalogue, and from 1889 on that of the 1880 Catalogue, which is the same as that for 1872.

| Catalogue. | Correction to Equinox. |
|---|---|
| 1861 ... ... ... ... ... | $-{}^{s}\cdot 01 \times \frac{5}{7}$ |
| 1864 ... ... ... ... ... | $-{}^{s}\cdot 01$ |
| 1872 ... ... ... ... ... | $+{}^{s}\cdot 007$ |
| 1880 ... ... ... ... ... | ·000 |

In order to reduce the right ascensions of the regular assistants referred to C. to the equinox of the Ten-Year Catalogue, 1880, for comparison with the Washington observations, we have applied a correction of $-{}^{s}\cdot 003$ to the years 1864–69, and $+{}^{s}\cdot 007$ to the years 1870–77.

Before we can directly compare the results of the Greenwich and Washington observations referred respectively to C. and E., it will be necessary to find the corrections required to reduce the tables of Hansen and Olufsen to those of Le Verrier. For this purpose we have taken the N.A. and A.E. places given for the Sun on the fifteenth day of each month as representing the mean monthly R.A.'s of observation, and tabulated the differences as corrections to the American Ephemeris (A.E.).

TABLE VIII.

*Comparison between the Tables of the Sun for the 15th day of each month of the years 1872–87, as given by the Greenwich and American Nautical Almanacs.*

R.A.

| | 1872 | 1873 | 1874 | 1875 | 1876 | 1877 | 1878 | 1879 | 1880 | 1881 | 1882 | 1883 | 1884 | 1885 | 1886 | 1887 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | s | s | s | s | s | s | s | s | s | s | s | s | s | s | s | s |
| Jan. 15 | +·05 | +·08 | +·05 | +·02 | ·00 | +·07 | +·04 | +·02 | +·06 | +·04 | +·04 | +·03 | +·01 | +·08 | +·04 | +·03 |
| Feb. 15 | +·01 | +·03 | −·01 | +·02 | −·01 | +·03 | +·05 | ·00 | +·02 | +·03 | +·01 | +·03 | +·02 | +·04 | +·06 | +·02 |
| Mar. 15 | ·00 | +·02 | −·02 | +·04 | +·01 | +·01 | +·05 | ·00 | +·01 | +·04 | −·02 | +·03 | +·03 | +·02 | +·05 | ·00 |
| Apr. 15 | +·03 | +·01 | −·04 | +·05 | +·01 | +·01 | +·04 | +·02 | +·02 | +·03 | ·00 | +·04 | +·04 | +·01 | +·07 | +·03 |
| May 15 | +·09 | ·00 | −·02 | +·06 | +·03 | +·05 | +·03 | +·04 | +·08 | +·03 | −·01 | +·07 | +·05 | +·04 | +·05 | +·06 |
| June 15 | +·08 | +·04 | +·04 | +·05 | +·03 | +·12 | +·06 | +·03 | +·08 | +·05 | +·04 | +·06 | +·07 | +·09 | +·07 | +·05 |
| July 15 | +·07 | +·02 | +·05 | +·06 | +·03 | +·10 | +·06 | +·05 | +·07 | +·04 | +·07 | +·06 | +·02 | +·08 | +·05 | +·05 |
| Aug. 15 | +·09 | ·00 | +·04 | +·09 | +·02 | +·05 | +·06 | +·10 | +·08 | +·02 | +·04 | +·06 | +·01 | +·05 | +·07 | +·06 |
| Sept. 15 | +·05 | +·02 | +·01 | +·04 | +·07 | +·05 | +·06 | +·08 | +·06 | +·04 | +·03 | +·07 | +·05 | +·03 | +·05 | +·06 |
| Oct. 15 | +·05 | +·06 | +·02 | +·02 | +·04 | +·05 | +·08 | +·07 | +·05 | +·06 | +·03 | +·02 | +·05 | +·03 | +·04 | +·03 |
| Nov. 15 | +·01 | +·07 | +·05 | +·01 | +·07 | +·05 | +·09 | +·08 | +·03 | +·08 | +·08 | +·01 | +·06 | +·02 | +·05 | +·05 |
| Dec. 15 | +·04 | +·09 | +·10 | +·03 | +·09 | +·08 | +·11 | +·10 | +·05 | +·06 | +·09 | +·05 | +·07 | +·05 | +·06 | +·06 |
| Mean | +·048 | +·037 | +·023 | +·041 | +·033 | +·056 | +·061 | +·049 | +·051 | +·043 | +·033 | +·044 | +·040 | +·045 | +·055 | +·042 |

These tables show a range in any year of about $0^s.1$, and a constant difference of about $0^s.05$. Before the correction to the equinox from the Greenwich and Washington observations can be properly compared, corrections should be applied for these monthly differences of tables. Roughly, the effect would be that of the mean for the year.

In the following table (IX.) we have converted the Washington corrections to the ephemeris of the Sun into tabular errors by changing the signs; the sum of the two columns 2 and 3 will then give in column 4 the Washington observed tabular errors of the Sun referred to Le Verrier's tables. The mean difference between the Greenwich and Washington results for the years 1872–87 ($-^s.051$) may be considered as the probable value of the personality of Professor Eastman referred to Mr. Criswick.

Correcting the Washington observations by this amount, we then have them in a form which we can directly compare with those made at Greenwich. For this purpose we have used only those Greenwich observations made by the regular observers, after applying to them the small correction for a uniform equinox mentioned above.

TABLE IX.

| Year. | Washington Tabular Errors of Sun in R.A. referred to E. as Standard (1). | Correction for Le Verrier's Tables (2). | Washington Tabular Errors of Sun in R.A. referred to Le Verrier's Tables and to E. as Standard. | Washington Tabular Errors of Sun in R.A. referred to Le Verrier's Tables and to C. as Standard. | Greenwich Tabular Errors of Sun in R.A. referred to C. and corrected to Equinox of the Ten-Year Catalogue, 1880. |
|---|---|---|---|---|---|
| | s | s | s | s | s |
| 1864 | ... | ... | ... | ... | +·025 |
| 1865 | ... | ... | ... | ... | +·049 |
| 1866 | ... | ... | ... | ... | ·000 |
| 1867 | ... | ... | ... | ... | +·002 |
| 1868 | ... | ... | ... | ... | +·019 |
| 1869 | ... | ... | ... | ... | +·044 |
| 1870 | ... | ... | ... | ... | +·037 |
| 1871 | ... | ... | ... | ... | +·027 |
| 1872 | +·052 | +·048 | +·100 | +·049 | +·018 |
| 1873 | +·030 | +·037 | +·067 | +·016 | +·040 |
| 1874 | +·009 | +·023 | +·032 | −·019 | +·065 |
| 1875 | +·009 | +·041 | +·050 | −·001 | +·036 |
| 1876 | +·033 | +·033 | +·066 | +·015 | +·036 |
| 1877 | +·022 | +·056 | +·078 | +·027 | +·028 |
| 1878 | +·055 | +·061 | +·116 | +·066 | +·026 |
| 1879 | +·011 | +·049 | +·060 | +·009 | +·016 |
| 1880 | +·033 | +·051 | +·084 | +·033 | +·014 |
| 1881 | +·026 | +·043 | +·069 | +·018 | +·017 |
| 1882 | +·042 | +·033 | +·075 | +·024 | +·020 |
| 1883 | +·045 | +·044 | +·089 | +·038 | +·015 |
| 1884 | +·030 | +·040 | +·070 | +·019 | +·012 |
| 1885 | +·050 | +·045 | +·095 | +·044 | +·006 |
| 1886 | +·023 | +·055 | +·078 | +·027 | +·023 |
| 1887 | +·038 | +·042 | +·080 | +·029 | +·016 |
| 1888 | ... | ... | ... | ... | +·021 |
| 1889 | ... | ... | ... | ... | +·034 |
| 1890 | ... | ... | ... | ... | +·008 |
| 1891 | ... | ... | ... | ... | +·033 |
| 1892 | ... | ... | ... | ... | +·003 |
| 1893 | ... | ... | ... | ... | +·013 |

The following six tables deal with the N.P.D. observations at Greenwich and Washington exactly in the same manner as was done in the case of the R.A.'s.

For Greenwich we have taken the years 1881–93 only, as they are in all respects strictly comparable; and as T. L. observed continuously throughout this period, we have taken him as our standard. For Washington we have taken the same period as in the R.A. observations, and referred them to E.

TABLE X.

*Greenwich Mean Tabular Errors of N.P.D. of Sun (mean of both limbs only).*

| | T. L. | No. of Obs. | T. | No. of Obs. | C. | No. of Obs. | A. D. | No. of Obs. | | Miscell. | No. of Obs. | Mean. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | " | | " | | " | | " | | | " | | " |
| 1881 | +·01 | 24 | +·52 | 17 | +·29 | 15 | −·31 | 23 | ... | +·29 | 29 | +·13 |
| | | | | | H. | | | | | | | |
| 1882 | +·47 | 17 | +·55 | 21 | +·87 | 25 | +·07 | 13 | ... | +·50 | 21 | +·55 |
| 1883 | −·55 | 22 | +·19 | 23 | +·22 | 20 | −·54 | 21 | ... | −·14 | 37 | +·16 |
| 1884 | −·58 | 20 | −·39 | 15 | −·01 | 15 | −·81 | 15 | ... | −·18 | 37 | −·35 |
| 1885 | −·55 | 20 | +·02 | 18 | +·06 | 28 | −·51 | 18 | ... | −·29 | 40 | −·23 |
| 1886 | +·12 | 17 | −·19 | 11 | +·51 | 28 | −·23 | 23 | ... | −·26 | 50 | −·03 |
| 1887 | −·17 | 18 | +·09 | 21 | +·44 | 26 | −·15 | 19 | ... | +·33 | 55 | +·18 |
| 1888 | +·55 | 16 | −·19 | 17 | +·52 | 15 | −·66 | 16 | ... | +·09 | 32 | +·16 |
| 1889 | +·40 | 17 | +·17 | 13 | +·31 | 19 | +·03 | 24 | ... | +·09 | 46 | +·16 |
| 1890 | +·11 | 23 | −·26 | 11 | +·06 | 30 | −·31 | 23 | ... | +·05 | 52 | −·02 |
| | | | | | | | | | A. C. | | | |
| 1891 | +·50 | 15 | +·04 | 15 | +·16 | 22 | −·54 | 13 | −·17 | 18 | +·17 | 44 +·07 |
| | | | B. | | | | T. H. | | | | | |
| 1892 | +·78 | 21 | +·14 | 21 | +·60 | 10 | +1·19 | 15 | +·31 | 32 | −·07 | 46 +·34 |
| 1893 | +·16 | 10 | +·01 | 27 | −·16 | 31 | +·92 | 11 | −·12 | 28 | +·18 | 66 +·09 |

TABLE XI.

*Corrections to reduce Table X. to T. L. as standard.*

A. D.—T. L. = −0".33
T.—T. L. = +0·09
H.—T. L. = +0·20
A. C.—T. L. = −0".52
B.—T. L. = −0·50
T. H.—T. L. = +0·49
Misc. = +0·05

TABLE XII.

*Greenwich Mean Tabular Errors of Sun in N.P.D. referred to T. L. as standard.*

| | T. L. | T. | | A. D. | | Miscell. | Mean of Assistants. | Mean of all. |
|---|---|---|---|---|---|---|---|---|
| | No. of Obs. | No. of Obs. | No. of Obs. | No. of Obs. | | No. of Obs. | No. of Obs. | |
| | " Obs. | " Obs. | | " Obs. | | " Obs. | " Obs. | " |
| 1881 | +·01 24 | +·43 17 | ... | +·02 23 | ... | +·24 29 | +·12 64 | +·16 |
| | | | H. | | | | | |
| 1882 | +·47 17 | +·46 21 | +·67 25 | +·40 13 | ... | +·45 21 | +·52 76 | +·51 |
| 1883 | −·55 22 | +·10 23 | +·02 20 | −·21 21 | ... | −·19 37 | −·12 86 | −·14 |
| 1884 | −·58 20 | −·48 15 | −·21 15 | −·48 15 | ... | −·23 37 | −·45 65 | −·31 |
| 1885 | −·55 20 | −·07 18 | −·14 28 | −·18 18 | ... | −·34 40 | −·22 84 | −·26 |
| 1886 | +·12 17 | −·28 11 | +·31 28 | +·10 23 | ... | −·31 50 | +·13 79 | −·04 |
| 1887 | −·17 18 | ·00 21 | +·24 26 | +·18 19 | ... | +·28 55 | +·08 84 | +·16 |
| 1888 | +·55 16 | −·28 17 | +·32 15 | −·33 16 | ... | +·04 32 | −·03 64 | −·01 |
| 1889 | +·40 17 | +·08 13 | +·11 19 | +·36 24 | ... | +·04 46 | +·26 73 | +·17 |
| 1890 | +·11 33 | −·35 11 | −·14 30 | +·02 23 | ... | ·00 52 | −·04 97 | −·03 |
| | | | | | A. C. No. of Obs. | | | |
| | | | | | " Obs. | | | |
| 1891 | +·50 15 | −·05 15 | −·04 22 | −·21 13 | +·35 18 | +·12 44 | +·12 82 | +·12 |
| | | B. | | T. H. | | | | |
| 1892 | +·78 21 | +·64 21 | +·40 10 | +·70 15 | +·83 32 | −·12 46 | +·71 99 | +·43 |
| 1893 | +·16 10 | +·51 27 | −·36 31 | +·43 11 | +·40 28 | +·13 66 | +·28 107 | +·22 |

TABLE XIII.

*Washington Corrections to Tabular N.P.D.'s of Sun from the American Ephemeris (mean of both limbs only).*

| | E. | | Sk. | | F. | | Hn. | | S. | | Mean. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No. of Obs. | | No. of Obs. | | No. of Obs. | | No. of Obs. | | No. of Obs. | | No. of Obs. |
| | " | | " | | " | | " | | " | | " | |
| 1872 | −0·50 | 35 | ... | | −0·42 | 21 | ... | | −0·01 | 17 | −0·37 | 73 |
| 1873 | +0·86 | 24 | ... | | −0·08 | 19 | +0·85 | 11 | +1·27 | 10 | +0·67 | 64 |
| 1874 | −0·21 | 26 | +0·56 | 24 | −0·74 | 16 | ... | | +0·42 | 14 | +0·02 | 80 |
| | | | | | | | P. | | | | | |
| 1875 | +1·33 | 24 | +0·80 | 26 | +0·82 | 21 | +1·30 | 16 | ... | | +1·04 | 87 |
| 1876 | +0·39 | 27 | +0·59 | 24 | −0·22 | 22 | +0·53 | 29 | ... | | +0·35 | 102 |
| | | | | | | | | | Pr. | | | |
| 1877 | +1·48 | 15 | +1·45 | 15 | +0·70 | 12 | +0·81 | 11 | ... | | +1·16 | 53 |
| 1878 | −0·49 | 11 | +0·14 | 18 | +0·01 | 11 | −0·31 | 11 | −0·23 | 8 | −0·14 | 59 |
| 1879 | +0·09 | 1 | +1·83 | 17 | +0·07 | 18 | +1·61 | 7 | +1·45 | 27 | +1·20 | 70 |
| | | | | | W. | | | | R. | | | |
| 1880 | +1·32 | 13 | +1·13 | 16 | +2·91 | 12 | +2·10 | 5 | +1·56 | 8 | +1·73 | 54 |
| 1881 | +1·47 | 15 | +1·46 | 12 | +1·57 | 23 | ... | | +1·22 | 32 | +1·40 | 82 |
| 1882 | −0·02 | 13 | +0·55 | 10 | +0·50 | 31 | ... | | +0·22 | 18 | +0·34 | 72 |
| 1883 | +1·87 | 20 | +1·47 | 18 | +1·95 | 14 | +0·37 | 3 | +1·89 | 15 | +1·72 | 70 |
| 1884 | +0·66 | 25 | +1·42 | 23 | +1·31 | 28 | +0·43 | 24 | ... | | +0·96 | 100 |
| 1885 | +0·65 | 24 | +0·89 | 20 | +1·58 | 31 | +0·17 | 12 | ... | | +0·97 | 87 |
| 1886 | −0·35 | 24 | +0·37 | 23 | +0·68 | 17 | +0·31 | 15 | ... | | +0·20 | 79 |
| 1887 | +0·48 | 14 | +0·65 | 28 | +0·38 | 22 | −0·12 | 17 | ... | | +0·39 | 81 |

TABLE XIV.

*Corrections to reduce Table XIII. to E. as standard.*

F.—E. = +0·42
Hn.—E. = +0·01
Sk.—E. = +0·19
Pr.—E. = −1·44
S.—E. = −0·31
R.—E. = +0·10
W.—E. = −0·51
P.—E. = +0·19

TABLE XV.

*Washington Observations.—Corrections to Tabular N.P.D.'s of Sun from the American Ephemeris referred to E. as standard.*

| | E. | | Sk. | | F. | | Hn. | | S. | | Mean. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ″ | No. of Obs. | ″ | No. of Obs. | ″ | No. of Obs. | ″ | No. of Obs. | ″ | No. of Obs. | ″ | No. of Obs. |
| 1872 | −0·50 | 35 | ... | | 0·00 | 21 | ... | | −0·32 | 17 | −0·31 | 73 |
| 1873 | +0·86 | 24 | ... | | +0·34 | 19 | +0·86 | 11 | +0·96 | 10 | +0·88 | 64 |
| 1874 | −0·21 | 26 | +0·37 | 24 | −0·32 | 16 | ... | | +0·11 | 14 | 0·00 | 80 |
| | | | | | | | P. | | | | | |
| 1875 | +1·33 | 24 | +0·61 | 26 | +1·24 | 21 | +1·49 | 16 | ... | | +1·12 | 87 |
| 1876 | +0·39 | 27 | +0·40 | 24 | +0·20 | 22 | +0·72 | 29 | ... | | +0·44 | 102 |
| 1877 | +1·48 | 15 | +1·26 | 15 | +1·12 | 12 | +1·10 | 11 | ... | | +1·23 | 53 |
| | | | | | | | | | Pr. | | | |
| 1878 | −0·49 | 11 | −0·05 | 18 | +0·43 | 11 | −0·12 | 11 | −1·67 | 8 | −0·08 | 59 |
| 1879 | +0·90 | 1 | +1·64 | 17 | +0·49 | 18 | +1·80 | 7 | +0·01 | 27 | +1·27 | 70 |
| | | | | | W. | | | | R. | | | |
| 1880 | +1·32 | 13 | +0·94 | 16 | +2·40 | 12 | +2·29 | 5 | +1·66 | 8 | +1·52 | 54 |
| 1881 | +1·47 | 15 | +1·27 | 12 | +1·06 | 23 | ... | | +1·32 | 32 | +1·13 | 82 |
| 1882 | −0·02 | 13 | +0·36 | 10 | −0·01 | 31 | ... | | +0·32 | 18 | +0·10 | 72 |
| 1883 | +1·87 | 20 | +1·28 | 18 | +1·44 | 14 | +0·56 | 3 | +1·99 | 15 | +1·56 | 70 |
| 1884 | +0·66 | 25 | +1·23 | 23 | +0·80 | 28 | +0·62 | 24 | ... | | +0·76 | 100 |
| 1885 | +0·65 | 24 | +0·70 | 20 | +1·08 | 31 | +0·36 | 12 | ... | | +0·77 | 87 |
| 1886 | −0·35 | 24 | +0·18 | 23 | +0·17 | 17 | +0·50 | 15 | ... | | +0·08 | 79 |
| 1887 | +0·48 | 14 | +0·46 | 28 | −0·13 | 22 | +0·07 | 17 | ... | | +0·22 | 81 |

In order to compare the tables employed in the English and American *Nautical Almanacs*, we append a table (XVI.) for the N.P.D.'s similar to Table VIII. for the R.A.'s.

## Table XVI.

*Comparison between the Tables of the Sun for the Fifteenth Day of each Month of the Years* 1872–87 *as given by the Greenwich and American Nautical Almanacs.*

N.P.D.

| | 1872 | 1873 | 1874 | 1875 | 1876 | 1877 | 1878 | 1879 | 1880 | 1881 | 1882 | 1883 | 1884 | 1885 | 1886 | 1887 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ |
| Jan. 15 | 0·0 | 0·0 | 0·0 | +0·2 | +0·4 | 0·0 | 0·0 | +0·1 | +0·1 | −0·1 | +0·1 | +0·1 | −0·2 | −0·1 | −0·1 | 0·0 |
| Feb. 15 | −0·1 | −0·2 | −0·1 | 0·0 | +0·1 | −0·1 | −0·2 | −0·1 | +0·1 | −0·2 | +0·1 | +0·1 | 0·0 | −0·2 | −0·2 | 0·0 |
| Mar. 15 | −0·3 | −0·2 | −0·1 | −0·3 | 0·0 | −0·2 | −0·4 | −0·2 | +0·1 | −0·3 | +0·1 | −0·2 | 0·0 | −0·3 | −0·2 | 0·0 |
| Apr. 15 | −0·3 | −0·3 | +0·1 | −0·3 | −0·1 | +0·1 | −0·3 | −0·2 | −0·2 | −0·3 | 0·0 | −0·5 | −0·2 | −0·3 | −0·4 | −0·3 |
| May 15 | −0·2 | −0·2 | −0·2 | −0·4 | −0·2 | −0·3 | −0·1 | −0·3 | −0·3 | −0·2 | −0·1 | −0·5 | −0·1 | −0·4 | −0·2 | −0·4 |
| June 15 | −0·4 | −0·2 | −0·2 | −0·2 | −0·3 | −0·3 | −0·2 | −0·2 | −0·2 | −0·1 | +0·1 | −0·2 | −0·3 | −0·2 | −0·1 | −0·3 |
| July 15 | −0·1 | −0·3 | 0·0 | −0·1 | 0·0 | +0·1 | 0·0 | 0·0 | +0·1 | −0·1 | +0·1 | +0·1 | −0·1 | 0·0 | +0·1 | 0·0 |
| Aug. 15 | +0·2 | −0·2 | +0·1 | +0·3 | +0·1 | +0·2 | +0·2 | +0·3 | +0·3 | −0·2 | +0·2 | +0·3 | 0·0 | +0·1 | +0·3 | +0·2 |
| Sept. 15 | +0·2 | +0·3 | −0·1 | +0·4 | +0·4 | +0·4 | +0·6 | +0·6 | +0·3 | +0·4 | +0·3 | +0·3 | +0·2 | +0·3 | +0·2 | +0·6 |
| Oct. 15 | +0·1 | +0·6 | +0·1 | +0·2 | +0·5 | +0·3 | +0·4 | +0·5 | +0·3 | +0·4 | +0·3 | +0·2 | +0·5 | +0·2 | +0·1 | +0·6 |
| Nov. 15 | +0·1 | +0·5 | +0·4 | +0·1 | +0·4 | +0·6 | +0·4 | +0·3 | +0·2 | +0·4 | +0·3 | +0·1 | +0·4 | +0·3 | +0·1 | +0·3 |
| Dec. 15 | −0·1 | +0·2 | +0·3 | 0·0 | +0·2 | +0·4 | +0·1 | −0·1 | 0·0 | +0·2 | +0·1 | −0·1 | 0·0 | +0·2 | +0·1 | +0·1 |
| Means | −0·08 | 0·0 | +0·03 | −0·01 | +0·13 | +0·10 | +0·04 | +0·06 | +0·07 | −0·01 | +0·13 | −0·03 | +0·02 | −0·03 | −0·03 | +0·07 |

It is apparent from these tables that there is a considerable amount of personality among the different observers in determining the position of the centre of the Sun in N.P.D., but the effects are not so general as in the case of the R.A. ; we have only exhibited them here to show their existence, for which there does not appear to be any reasonable cause, as there is little or no motion in the direction of measurement, and otherwise the conditions are nearly the same for both limbs. The still large remaining discordances in the correction to the equinox, after allowing for the personality of observers in making R.A. observations, and considering the apparently small mean annual error in the N.P.D. Greenwich observations, appear to suggest some periodical error in the tables or observations, which may form, we hope, the subject of a future communication.

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## *Photograph of the Nebulæ* M 78 *and* H IV. 36 *Orionis.*

By Isaac Roberts, D.Sc., F.R.S.

The photograph of the nebulæ M 78 and H IV. 36 *Orionis*, R.A. $5^h$ $41^m$, Decl. 0° 1′ north, was taken with the 20-inch reflector on 1894 January 28, with exposure of the plate during three hours, and the copy now presented is enlarged to the scale of 1 millimetre to 24 seconds of arc.

The nebulæ are Nos. 2,068 and 2,071 in the *New General Catalogue*, and Nos. 1,267, 1,270 in the *General Catalogue*.

The nebula M 78 (*N. G. C.* No. 2,068) is described by Sir J. Herschel as bright, large, wispish, very gradually much brighter in the middle, three stars involved, barely resolvable. In the *Phil. Trans.* 1833, pl. xii., fig. 36, a drawing of it is given which, in outline, resembles the central part of the nebulosity. The nebula H IV. 36 (*N. G. C.* No. 2,071) is described as a star with very faint large *chevelure*.

Lord Rosse (*Observations of Nebulæ and Clusters of Stars*, p. 51) gives the results of nine observations made between the years 1850 and 1877, and states that a "spiral arrangement is sufficiently seen to confirm former observations." A marginal sketch is given, and a drawing on pl. i., fig. 5 ; but they are not like the photograph, and they quite fail to indicate the form of the nebula as it is there shown.

The photograph shows the central part of the nebula as a dense cloud with a well-defined margin on the n.p. side, and the three stars referred to by Herschel and Rosse are shown involved in the nebulosity. The star on the northern edge has a faint companion, and faint star-like condensations are also seen involved in the nebulosity. There are flocculent clouds of nebulosity surrounding the dense central part, with wide dark spaces between them, which the descriptive matter and the drawings by Sir J. Herschel and Lord Rosse fail to indicate.

The nebula H IV. 36 (*G. C.* 1,270) has a stellar nucleus, with a small companion star close to it on the south side, and this double nucleus is surrounded by cloud-like streaky nebulosity.

The distance between the centres of the nebulæ is about 15 minutes of arc, and there are indications that the two nebulæ are connected together with very faint nebulosity, but there is no spiral form (as suggested by Lord Rosse) visible in either of them.

The sky within a radius of about half a degree of these nebulæ is remarkably void of stars, but beyond this distance, both *preceding* and *following*, the stars are crowded on the plate.

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*Photograph of the Nebula* M 74 *Piscium.*
By Isaac Roberts, D.Sc., F.R.S.

The photograph of the nebula M 74 *Piscium*, R.A. $1^h\ 31^m$, Decl. 15° 15′ north, was taken with the 20-inch reflector on 1893 December 9, with exposure of the plate during three hours and forty minutes, and the copy now presented is enlarged to the scale of 1 millimetre to 15 seconds of arc.

The nebula is No. 628 in the *New General Catalogue* and 372 in the *General Catalogue.*

Sir J. Herschel (*G. C.* 372, p. 52) states as the result of eleven observations that it is a globular cluster, faint, very large, round, pretty suddenly much brighter in the middle, partially resolved.

Lord Rosse (*Phil. Trans.* 1861, p. 711) designates it as a spiral nebula with the centre formed of stars, and several stars visible through the nebula. A marginal sketch shows the spiral form, and in the *Observations of Nebulæ and Clusters of Stars*, p. 21, another marginal sketch is given which shows a nucleus and five stars involved in the spirals.

The photograph shows the nebula to be a very perfect spiral, with a central stellar nucleus and a 15th mag. star close to it on the south side. The convolutions of the spiral are studded with many stars and star-like condensations, and on the *north preceding* side there is a partial inversion of one of the convolutions, which conveys the idea of some irregular disturbing cause having interfered with the regular formation of a part of that convolution.

The photograph cannot be adequately described, it must be examined before it can be fully appreciated.

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## *Note on the Solar Eclipse of* 1598. By J. L. E. Dreyer, Ph.D.

On 1598 February 25 (March 7) an eclipse of the Sun took place which was extensively observed in Germany. At that time Tycho Brahe, who had left Denmark in the previous summer, was staying at Wandsbeck in Holstein, close to Hamburg, and observed the eclipse there. His assistant, Longomontanus, observed it at Rostock, and a former assistant, Christen Hansen, observed it in Jutland. It is, however, more interesting that the eclipse was watched at the deserted observatory on the island of Hveen with one of the four great instruments which had been left behind on Tycho's departure from the island, and which were not removed till towards the end of 1599. As I had last year an opportunity of examining the particulars of this observation in the original MS. volume of observations from the year 1598, in the Royal Library of Copenhagen, a short account of it may not be uninteresting to the Society, particularly as some writers seem to have doubted that the eclipse was actually observed at Hveen.

In a letter to Magini, dated from Dresden 1598 November 28,* Tycho gives the following particulars about this eclipse :

"Martii d. 6. Eclipsis ☉ medium $11^h$ 5′ a.mn. Uraniburgi in Dania. Magnitudo Eclipsationis ibidem apparuit a parte superiori intra 9 et 10 digitos."

He adds that all this agrees well with his own tables. In another letter to Magini from Prague, of 1601 January 24,† Tycho again alludes to this eclipse as having been observed at Uraniborg with one of the instruments left there. He refers for details to a paper enclosed in the letter, but this paper appears to have been lost. Some further particulars are, however, given in a letter to Kepler of 1599 December 9.‡ In this Tycho first states that according to his own tables the magnitude of the eclipse should be $9\frac{1}{2}$ digits, and continues : "qua etiam quantitate Sol deficere a quodam ex meis Uraniburgi isthic (ut 4 residuorum instrumentorum, quae prae magnitudine efferri tam cito nequibant, curam haberet) relicto studioso deprehensus est, et tempora alias per armillam aequatoriam, 18 pedum in diametro, a principio usque ad finem (fuit enim toto isthic tempore serenum) meae restitutioni apprime congruentia coelitus denotata sunt, quae erant ejuscemodi, ut deliquium inciperet isthic h. 10.10′, finem haberet h. 12.19′, ideoque medium existeret h. 11.12′."

In his book on optics (*Paralipomena in Vitellionem*, cap. xi.) Kepler discusses the observations of this eclipse, and states that it was by a student of Tycho's observed to commence at $10^h$ $3^m$ and to end at $12^h$ $32^m$, the duration being $2^h$ $29^m$. In the *Tabulae Rudolphinae* (pp. 110, 111) this eclipse is used as an

* *Carteggio inedito di Ticone Brahe . . . con G. A. Magini*, p. 222.
† *Ibid.* p. 238.
‡ *Opera Omnia*, ed. Frisch, i. 225.

example of the method for computing an eclipse for a particular locality, and it is shown that it lasted $2^h\ 21^m$. Kepler adds that the longer duration given in his *Optics* was erroneous: "Quin etiam addita observatio, tanquam Uraniburgica, quamvis neque Tychonis sit, qui tunc insula excesserat, nec Uraniburgica omnino, durationem tamen tantam convellit. Apparet enim ex fine h. 12.32′, observationem esse Origani Frankofurdiani ad Oderam, qui hunc finem annotat: initium autem expressit sic: h. $10\frac{1}{3}$, quod alius superveniens legit h. 10.3′."

Did Kepler, then, when writing this, believe that the eclipse had *not* been observed at Uraniborg? It almost seems so, and Frisch evidently is of this opinion when using the expression, "De observatore Huennensi, seu potius Francofurtensi, vide annotationem sequentem," before reprinting the sentences quoted above.* And yet Kepler might easily have satisfied himself that the figures given in his *Optics* were not those deduced by Tycho from the observation made at Hveen, as Tycho's manuscripts were in his possession, though possibly he had not all of them at hand when writing the text to the *Tabulae Rudolphinae*.

In the MS. volume containing Tycho's original observations made during the years 1598 and 1599 the account of the observations made at Hveen is headed: "Eclipsis Solis Anni 1598 Mense Feb. die 25 Vraniburgi obseruata." Then follow sixteen diagrams of the solar disc with some figures beside each, which evidently represent the corresponding hour angles of the Sun. The first diagram shows that the Moon has already entered on the solar disc some five or six minutes before, as more than a tenth part of the solar diameter is eclipsed, and next it is written: "Tunc fuit Sol orienta. $26^g\ 25^m$, H. $10\ 14\frac{1}{3}$," underneath which is written in Tycho's own hand: "Pone initium 28 graduum." At the following diagrams the hour angles are only given in degrees and minutes, not in time; and after the second one Tycho has written: "Sic Tycho . . . initium 10.10" (the dots represent an illegible word). The fourteenth diagram shows that the last contact is close at hand, and next it is written: "Sol occidentalis $\begin{matrix}4 & 40\\ 0^H & 18^M\end{matrix}$" to which Tycho adds: "Tycho fecit finem 12.19." Diagrams 15 and 16 are only blank circles with the hour angles 7.15 and 7.20, showing that the eclipse was over. The whole account occurs also in a quarto volume which contains copies (not originals) of observations made in 1593, 1590, and 1598–1600,† the only difference being that Tycho's concluded times of beginning and end of the eclipse are not given in this volume.

* *Opera Omnia*, ii. 441.

† This volume is numbered "1828, 4to," see my *Tycho Brahe*, p. 391, footnote 3. Probably the first part of the volume, containing observations made in 1593, has belonged to the set of quarto volumes used by Albert Curtz for the compilation of the well-known *Historia Coelestis*, as the year 1593 is omitted in the latter.

All this is in perfect accordance with the particulars quoted above from Tycho Brahe's letter to Kepler of 1599 December 9, and if the figures given by Kepler in the *Paralipomena* were copied from Origanus, this mistake was Kepler's own, and not Tycho's, as the latter concluded from the diagrams made at Uraniborg that the eclipse began for that place at $10^h\ 10^m$ and ended at $12^h\ 19^m$.

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## *Note on the Proper Motion of the Star L L* 38239.

By J. L. E. Dreyer.

The magnitude of this star is given as 7·6 in the *Durchmusterung*, and it follows about $1^m$ after the Dumb Bell Nebula. I am not aware that the Proper Motion has been noticed before. The following positions are for 1890·0 and are referred to Auwers' fundamental system ; Lalande's and Bessel's observations have been reduced anew by Asten's and Luther's tables.

| | h m s | ° ′ ″ | | |
|---|---|---|---|---|
| Lalande 38239 | 19 55 58·35 | +22 25 25·5 | (1 obs.) | 1796·6 |
| Bessel (W. 1792) | 58·72 | 13·1 | (1 obs.) | 1825·7 |
| Rümker 7900 | 58·63 | 8·3 | (4 obs.) | 1840 |
| Bonn (Beob. Bd. vi.) | 58·79 | 3·8 | (3 obs.) | 1862·6 |
| Berlin Zone | 58·76 | 24 59·4 | (2 obs.) | 1881·7 |
| Copenhagen, Pechüle | 58·79 | 56·5 | (2 obs.) | 1893 7 |

The last observation was kindly made at my request. Lalande has two wire-transits in good accordance *inter se*. A proper motion $= +0^s{\cdot}0032$ and $-0''{\cdot}252$ represents these observations as follows :—

| | h m s | ° ′ ″ |
|---|---|---|
| Lalande | 19 55 58·65 | +22 24 62·0 |
| Bessel | 58·92 | 56·9 |
| Rümker | 58·79 | 55·7 |
| Bonn | 58·88 | 56·9 |
| Berlin | 58·79 | 57·3 |
| Copenhagen | 58·78 | 57·4 |

*Armagh Observatory,*
1894 *May.*

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*A New Variable Star of Type IV.* By the Rev. T. E. Espin, M.A.

On the night of 1893 September 16, while sweeping on the confines of *Lyra* and *Cygnus*, I came upon a fine red star which was found to be missing in *Argelander*. The place of this star for 1855 is

R.A. $19^h\ 15^m\ 2^s{\cdot}7$ Decl. $+37°\ 36'{\cdot}6$

The place depending on D.M. $+37°{\cdot}3420$.

The following are my observations of the star :—

1893 Sept. 16, Mag. 9·0

Nov. 13, Mag. 9·0

On the first of these nights the spectrum was believed to be Type IV., but its faintness made me feel some uncertainty about it. On March 29 I set for this star in strong twilight, and was at once struck by its increased brilliancy. I rated it 8·3, and found the bands quite obvious, even in the dawn. On April 10 I set for it again, and rated it 8·5. The spectrum was found to be Type IV., but band No. 9 of Dunér's nomenclature is of such a size and intensity as to cause the spectrum to appear a mere fragment. With careful attention I could make out band No. 6, but as faint as No. 9 was strong. The first appearance of the spectrum was unique, as it appeared continuous, but with the least refrangible end completely absorbed. The telescope was turned immediately afterwards upon *Es-Birm* 608, a fourth-type star, somewhat brighter, and the contrast with the perfectly normal Type IV. spectrum was very striking. Unfortunately a temporary derangement of the second spectroscope prevented fuller observation.

*Towlaw, Darlington:*
1894 *April* 11.

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*Note on the Red Spot of Jupiter.* By Joseph Gledhill, Bermerside Observatory, Halifax.

This object was carefully observed whenever seen on the disc. The whole outline was never steadily seen between 1893 January and 1894 March. No trace of colour was ever seen within the faint elliptic outline. Sometimes the following end of the ellipse was better seen than the preceding end ; at other times the two ends appeared stronger than the middle part. The best view was obtained on 1893 December 23, when the whole outline was distinctly seen at moments of best definition ; the spot was then not far from the western limb. It was last seen on 1894 February 9, as a very faint elliptic outline without colour.

*Observations of the Phenomena of Jupiter's Satellites at Bermerside Observatory, Halifax, in the years* 1892 *and* 1893. By Joseph Gledhill.

| Day of Obs. | Satellite. | Phenomenon. | Phase. | G.M.T. of Observation. | *N. Almanac* Time. | Remarks. |
|---|---|---|---|---|---|---|
| 1893. | | | | h m s | h m s | |
| Jan. 2 | III. | Tr. I. | Ext. contact. | 8 40 | 8 39 | Definition poor. |
| | | | Bisection. | 8 43 30 | | |
| | | | Int. contact. | 8 46 45 | | |
| 4 | I. | Oc. D. | Ext. contact. | 6 21 10 | 6 22 | Misty. |
| | | | Bisection. | 6 23 14 | | |
| | | | Just gone. | 6 25 7 | | |
| | I. | Ec. R. | First seen. | 9 54 41 | 9 54 15 | Very misty; planet low. |
| | | | Half out? | 9 56 | | |
| | | | Full? | 9 59 | | |
| 13 | I. | Ec. R. | First seen. | 6 19 14 | 6 18 58 | Often cloudy. |
| | | | Half out? | 6 21 | | |
| | | | Full? | 6 23 | | |
| | III. | Ec. D. | Last seen. | 8 25 2 | 8 23 13 | |
| | III. | Ec. R. | First seen. | 10 7 32 | 10 11 39 | Planet low; bad sky. |
| | | | Half out? | 10 9 | | |
| | | | Full? | 10 12 30 | | |
| 14 | II. | Tr. I. | Ext. contact. | 7 16 27 | 7 18 | Fair definition. |
| | | | Bisection. | 7 17 30 | | |
| | | | Int. contact. | 7 19 34 | | |
| 16 | II. | Ec. R. | First seen. | 6 35 15 | 6 34 31 | |
| | | | Half out? | 6 37 | | |
| | | | Full? | 6 40 | | |
| 20 | III. | Oc. D. | Ext. contact. | 6 41 11 | 6 46 | Fair definition. |
| | | | Bisection. | 6 45 17 | | |
| | | | Last seen. | 6 50 34 | | |
| | I. | Ec. R. | First seen. | 8 14 36 | 8 14 44 | |
| | | | Half out? | 8 16 | | |
| | | | Full? | 8 19 | | |
| | III. | Oc. R. | Bisection. | 9 10 14 | 9 16 | Planet low; bad definition. |
| | | | Ext. contact. | 9 13 17 | | |
| 27 | I. | Oc. D. | Ext. contact. | 6 42 13 | 6 43 | Poor definition. |
| | | | Last seen. | 6 45 9 | | |

| Day of Obs. | Satellite. | Phenomenon. | Phase. | G.M.T. of Observation. h m s | *N. Almanac* Time. h m s | Remarks. |
|---|---|---|---|---|---|---|
| 1893. | | | | | | |
| Feb. 5 | I. | Ec. R. | First seen. | 6 35 38 | 6 35 1 | |
| | | | Half out? | 6 38 | | |
| | | | Full? | 6 41 | | |
| 8 | II. | Sh. I. | First seen. | 7 13 | 7 14 | Windy, cloudy, much motion. |
| | | | Int. contact. | 7 15 19 | | |
| | II. | Tr. E. | Int. contact. | 7 18 4 | 7 22 | |
| | | | Ext. contact. | 7 25 10 | | |
| 11 | I. | Tr. I. | Ext. contact. | 7 51 8 | 7 50 | Much boiling on limb of planet. |
| | | | Bisection? | 7 52 5 | | |
| | | | Int. contact. | 7 55 9 | | |
| Aug. 14 | I. | Tr. I. | Int. contact. | 12 14 | 12 10 | Planet very low in E. |
| | I. | Sh. E. | Int. contact. | 12 59 14 | 12 59 | |
| Sept. 11 | II. | Ec. R. | First seen. | 10 24 22 | 10 23 15 | Planet very low; much motion. |
| | | | Half out? | 10 27 | | |
| | II. | Oc. D. | Ext. contact. | 10 46 | 10 45 | |
| | | | Half gone? | 10 47 | | |
| | | | Just gone? | 10 48 | | |
| 14 | I. | Ec. D. | Fading. | 10 0 | 10 1 41 | Violent motion; planet low. |
| | | | Half gone? | 10 1 | | |
| | | | Just gone. | 10 2 | | |
| 21 | III. | Oc. D. | Ext. contact. | 10 8 | 10 6 | Much motion. |
| | | | Bisection. | 10 15 | | |
| | | | Last seen. | 10 20 | | |
| | III. | Oc. R. | First seen. | 11 10 | 11 23 | Bad definition. |
| | | | Bisection. | 11 15 | | |
| | | | Ext. contact. | 11 20 | | |
| | I. | Ec. D. | Fading. | 11 53 | 11 55 43 | Bad definition. |
| | | | Half gone. | 11 55 | | |
| | | | Just gone. | 11 56 15 | | |
| 23 | I. | Oc. R. | First seen. | 9 44 30 | 9 45 | Violent motion; clouds showery. |
| | | | Bisection. | 9 45 30 | | |
| | | | Ext. contact. | 9 46 30 | | |
| 29 | I. | Sh. I. | First seen. | 11 8 | 11 8 | |
| | | | Int. contact. | 11 10 | | |
| Oct. 1 | I. | Tr. E. | Ext. contact. | 8 53 | 8 53 | Planet very low; bad sky. |
| 4 | II. | Tr. I. | Ext. contact. | 12 10 12 | 12 9 | Definition bad. |

| Day of Obs. | Satellite. | Phenomenon. | Phase. | G.M.T. of Observation. | *N. Almanac* Time. | Remarks. |
|---|---|---|---|---|---|---|
| 1893. | | | | h m s | h m s | |
| Oct. 4 | II. | Tr. I. | Bisection. | 12 12 37 | | |
| | | | Int. contact. | 12 14 30 | | |
| 6 | II. | Oc. R. | Half out. | 9 27 | 9 26 | Planet low; much motion. |
| | | | Ext. contact. | 9 29 | | |
| 8 | I. | Tr. I. | Ext. contact. | 8 27 | 8 28 | Planet very low. |
| | | | Int. contact. | 8 30 | | |
| | I. | Sh. E. | Int. contact. | 9 42 17 | 9 42 | |
| | | | Just off. | 9 44 | | |
| | I. | Tr. E. | Int. contact. | 10 35 | 10 39 | |
| | | | Bisection. | 10 36 | | |
| | | | Ext. contact. | 10 38 30 | | |
| 16 | I. | Oc. R. | Half out? | 9 32 | 9 33 | Stormy; bad definition. |
| | | | Ext. contact. | 9 34 | | |
| | III. | Tr. I. | First contact. | 10 43 | 10 45 | Very difficult and uncertain observation. Sat. moved along south limb of planet. |
| | | | Bisection. | 10 54 | | |
| | | | Quite on disc. | 11 5 | | |
| | III. | Tr. E. | Half off. | 11 48 | 11 57 | As above; clouds. |
| 22 | II. | Tr. E. | Bisection. | 8 13 | 8 13 | Clouds. |
| Dec. 9 | I. | Tr. I. | Ext. contact. | 5 40 | 5 39 | Good definition. |
| | | | Bisection. | 5 42 | | |
| | | | Int. contact. | 5 44 | | |
| | I. | Sh. I. | Int. contact. | 6 13 | 6 11 | |
| | II. | Ec. R. | First seen. | 6 41 20 | 6 42 57 | |
| | | | Half out? | 6 44 | | |
| | | | Full? | 6 48 | | |
| | I. | Tr. E. | Int. contact. | 7 48 16 | 7 50 | |
| | | | Bisection. | 7 50 39 | | |
| | | | Ext. contact. | 7 52 42 | | |
| | I. | Sh. E. | Int. contact. | 8 20 27 | 8 23 | |
| | | | Half off. | 8 22 34 | | |
| 15 | I. | Oc. D. | Ext. contact. | 10 8 12 | 10 9 | Stormy. |
| | | | Half gone. | 10 9 51 | | |
| | | | Just gone. | 10 10 30 | | |
| 16 | III. | Ec. D. | Fading. | 5 10 | 5 13 42 | Often cloudy. |
| | | | Half gone? | 5 12 | | |
| | | | Just gone. | 5 16 25 | | |

| Day of Obs. | Satellite. | Phenomenon. | Phase. | G.M.T. of Observation. h m s | *N. Almanac* Time. h m s | Remarks. |
|---|---|---|---|---|---|---|
| 1893. | | | | | | |
| Dec. 16 | II. | Oc. D. | Ext. contact. | 5 36 | 5 38 | |
| | III. | Ec. R. | Half out? | 6 48 | 6 49 40 | Cloudy. |
| | I. | Tr. I. | Ext. contact. | 7 26 43 | 7 23 | |
| | | | Bisection. | 7 27 17 | | |
| | | | Int. contact. | 7 28 30 | | |
| | I. | Sh. I. | Int. contact. | 8 7 19 | 8 6 | |
| | II. | Ec. R. | First seen. | 9 18 10 | 9 18 21 | |
| | | | Half out? | 9 20 | | |
| | | | Full? | 9 23 | | |
| | I. | Tr. E. | Int. contact. | 9 33 5 | 9 35 | |
| | | | Bisection. | 9 35 27 | | |
| | | | Ext. contact. | 9 37 18 | | |
| 17 | I. | Ec. R. | First seen. | 7 27 | 7 29 21 | Clouds passing. The sat. had been out several seconds when first seen at $7^h\ 27^m$. |
| 23 | III. | Oc. R. | Half off? | 7 18 7 | 7 27 | A difficult observation, owing to way in which the sat. came off. |
| | | | Ext. contact? | 7 26 12 | | |
| | II. | Oc. D. | Ext. contact. | 7 55 14 | 7 56 | Clouds passing. |
| | | | Bisection. | 7 58 23 | | |
| | | | Just gone. | 7 59 19 | | |
| | I. | Tr. I. | Ext. contact. | 9 10 6 | 9 9 | |
| | | | Bisection. | 9 13 17 | | |
| | | | Int. contact. | 9 15 42 | | |
| | III. | Ec. D. | Fading. | 9 15 | 9 15 31 | Clouds passing. |
| | | | Still visible. | 9 17 | | |
| 25 | II. | Tr. E. | Ext. contact. | 4 49 | 4 51 | Bad definition; clouds passing. |
| | | | Bisection. | 4 52 | | |
| | II. | Sh. E. | Int. contact. | 6 38 | 6 37 | Violent motion. |
| 30 | III. | Oc. D. | Ext. contact. | 9 13 17 | 9 16 | |
| 1894. | | | | | | |
| Jan. 1 | I. | Sh. I. | Int. contact. | 6 24 30 | 6 24 | |
| | I. | Tr. E. | Int. contact. | 7 32 18 | 7 36 | |
| | | | Bisection. | 7 34 6 | | |
| | | | Ext. contact. | 7 37 15 | | |
| | I. | Sh. E. | Int. contact. | 8 34 10 | 8 37 | |
| | II. | Sh. E. | Int. contact. | 9 10 47 | | Not given in *N. Almanac*. |
| 2 | I. | Ec. R. | First seen. | 5 48 19 | 5 49 42 | Hazy sky. |

| Day of Obs. | Satellite. | Phenomenon. | Phase. | G.M.T. of Observation. | *N. Almanac* Time. | Remarks. |
|---|---|---|---|---|---|---|
| 1894. | | | | h m s | h m s | |
| Jan. 17 | I. | Tr. E. | Int. contact. | 5 39 16 | 5 43 | |
| | | | Bisection. | 5 42 21 | | |
| | | | Ext. contact. | 5 45 17 | | |
| | III. | Tr. I. | Ext. contact. | 6 26 | 6 27 | Very difficult, owing to way in which sat. is moving. Times uncertain to at least 1m. |
| | | | Bisection. | 6 33 | | |
| | | | Int. contact. | 6 39 | | |
| | II. | Oc. R. | Ext. contact. | 6 36 | 6 38 | |
| | I. | Sh. E. | Int. contact. | 6 51 | 6 56 | Overcast; rain. |
| 22 | I. | Tr. I. | Ext. contact. | 10 54 | 10 54 | |
| | | | Int. contact. | 10 58 | | |
| 23 | I. | Oc. D. | Ext. contact. | 8 8 51 | 8 11 | |
| | | | Bisection. | 8 11 7 | | |
| | | | Just gone. | 8 13 13 | | |
| | I. | Ec. R. | First seen. | 11 36 58 | 11 37 17 | |
| 31 | I. | Tr. I. | Ext. contact. | 7 17 8 | 7 15 | |
| | | | Bisection. | 7 19 13 | | |
| | | | Int. contact. | 7 21 10 | | |
| | I. | Sh. I. | Int. contact. | 8 35 46 | 8 34 | |
| | II. | Oc. D. | Ext. contact. | 9 14 42 | 9 16 | |
| | | | Bisection. | 9 16 31 | | |
| | | | Just gone. | 9 18 24 | | |
| | I. | Tr. E. | Int. contact. | 9 25 27 | 9 28 | |
| | | | Bisection. | 9 27 16 | | |
| | | | Ext. contact. | 9 29 18 | | |
| Feb. 2 | II. | Tr. E. | Int. contact. | 6 27 18 | 6 34 | Stormy; raining. |
| | | | Bisection. | 6 29 27 | | |
| | | | Ext. contact. | 6 31 23 | | |
| 4 | III. | Oc. R. | Ext. contact. | 5 51 24 | 5 53 | Stormy; cloudy. |
| 8 | I. | Oc. D. | Ext. contact. | 6 26 5 | 6 27 | Stormy. |
| | | | Bisection. | 6 28 14 | | |
| | | | Just gone. | 6 30 18 | | |
| | I. | Ec. R. | First seen. | 9 57 38 | 9 58 2 | |
| | | | Half out? | 10 0 | | |
| | | | Full? | 10 2 | | |
| 9 | II. | Tr. I. | Ext. contact. | 6 41 19 | 6 47 | Stormy; cloudy. |
| 18 | II. | Oc. R. | First seen. | 6 5 20 | 6 8 | Hazy. |

| Day of Obs. | Satellite. | Phenomenon. | Phase. | G.M.T. of Observation. | *N. Almanac* Time. | Remarks. |
|---|---|---|---|---|---|---|
| 1894. | | | | h m s | h m s | |
| Feb. 18 | II. | Oc. R. | Ext. contact. | 6 6 40 | | |
| | II. | Ec. D. | Fading. | 6 22 | 6 25 19 | Hazy. |
| | | | Just gone. | 6 24 26 | | |
| | II. | Ec. R. | First seen. | 8 41 17 | 8 41 27 | Clear sky. |
| | | | Half out? | 8 43 15 | | |
| | | | Full? | 8 45 12 | | |
| 24 | I. | Ec. R. | First seen. | 8 18 27 | 8 18 47 | Wind and snow showers; some thin cloud. |
| Mar. 1 | III. | Tr. E. | Ext. contact. | 8 20 | 8 20 | Stormy. |
| | | | Bisected. | 8 16 | | |
| 4 | I. | Sh. E. | Int. contact. | 7 24 | 7 26 | Bad definition. |
| | II. | Oc. D. | Ext. contact. | 9 0 17 | 9 3 | Bad definition. |
| | | | Bisection. | 9 2 10 | | |
| | | | Just gone. | 9 4 32 | | |

*Notes.*

(Instrument: The 9½-inch Cooke Refractor, power 240.)

January 14, 1893.—II. Tr. I. The satellite is as bright as the limb of *Jupiter*, perhaps a little brighter. It did not lose any of its apparent brightness as it approached the limb.

February 8.—II. Tr. E. The satellite was not visible till $7^h\ 10^m$; it was on a bright zone.

August 14.—Satellite I. was invisible at $13^h$; it passed on to disc at $12^h\ 14^m$.

September 21.—III. Oc. D. The satellite passed behind the disc near the N. pole of *Jupiter*; seemed to skirt the limb; very difficult to observe the phases of the phenomenon.

October 8.—I. Tr. I. The satellite became invisible soon after it had passed on to the disc; it seemed much brighter than the adjacent bright surface of *Jupiter* just before its transit began.

December 9.—I. Tr. I. The satellite was invisible at $6^h\ 15^m$.

December 16.—I. Tr. I. It was invisible at $8^h$ and at $9^h\ 15^m$.

January 31, 1894.—I. was invisible at $8^h$, so also at $9^h$ and $9^h\ 15^m$.

January 17.—I. in transit; not visible at $5^h$, nor at $5^h\ 30^m$; on a grey belt close to a bright zone.

III. Tr. I. Very difficult to say when satellite is just in external contact; satellite not far from S. pole of planet. Similar case on October 16, 1893.

February 18.—II. Oc. R. The satellite when just past external contact looked very small in the dark sky.

*Differences of R.A. and N.P.D. of Uranus and 8 Libræ and a Libræ about the time of the conjunction in 1894 April, observed with the Transit-circle at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

*Comparisons with 8 Libræ.*

| Day. 1894. | Observer. | ♅−✳ R.A. | Assumed R.A. of ✳. | Apparent R.A. of ♅. | Secs. of Tab. R.A. | Error of Tab. R.A. | ♅−✳ N.P.D. | Assumed N.P.D. of ✳. | Apparent N.P.D. of ♅. | Secs. of Tab. N.P.D. | Error of Tab. N.P.D. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | m s | h m s | h m s | s | s | ′ ″ | ° ′ ″ | ° ′ ″ | ″ | ″ |
| Apr. 18 | B. | +1 35·10 | 14 44 51·27 | 14 46 26·37 | 26·74 | +0·37 | +4 50·70 | 105 33 38·92 | 105 38 29·62 | 30·5 | +0·88 |
| 21 | A. C. | +1 6·11 | 51·31 | 45 57·42 | 57·82 | +0·40 | +2 40·85 | 39·02 | 36 19·87 | 20·7 | +0·83 |
| 27 | C. D. | +0 7·03 | 51·38 | 44 58·41 | 58·74 | +0·33 | ... | ... | ... | ... | ... |
| 30 | A. C. | −0 23·00 | 51·42 | 44 28·42 | 28·79 | +0·37 | −4 0·65 | 39·42 | 29 38·77 | 40·5 | +1·73 |

*Comparisons with a Libræ.*

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Apr. 18 | B. | +1 23·67 | 14 45 2·71 | 14 46 26·38 | 26·74 | +0·36 | +2 8·65 | 105 36 19·90 | 105 38 28·55 | 30·5 | +1·95 |
| 21 | A. C. | +0 54·69 | 2·75 | 45 57·44 | 57·82 | +0·38 | +0 1·36 | 20·05 | 21·41 | 20·7 | −0·71 |
| 30 | A. C. | −0 34·49 | 2·86 | 44 28·37 | 28·79 | +0·42 | −6 41·30 | 20·50 | 39·20 | 40·5 | +1·30 |

The assumed mean places of the stars for 1894·0 are as follows :—

| | | | |
|---|---|---|---|
| 8 Libræ | R.A. 14 h 44 m 49·36 | N.P.D. 105° 33′ 23″·42 | Authority, Greenwich Ten Year Catalogue, 1880. |
| a „ | „ 14 45 0·79 | „ 105 36 4·50 | „ „ Five Year Catalogue of Fundamental Stars, 1890. |

In all cases the stars and planet were observed in the same position of the instrument.
The N.P.D differences have been corrected for refraction and parallax.
The tabular places for *Uranus* are those given in the *Nautical Almanac*.
The initials A. C., B., C. D. are those of Mr. Crommelin, Mr. Bryant, and Mr. Davidson, respectively.

*Royal Observatory, Greenwich:*
1894 *May* 9.

## *Observations of Gale's Comet (b 1894), made at the Royal Observatory, Greenwich.*

*(Communicated by the Astronomer Royal.)*

The observations were made with the East, or Sheepshanks, equatorial, aperture 6·7 inches, by taking transits over two cross-wires at right angles to one another, and each inclined 45° to the parallel of declination. Magnifying power, 55.

| Greenwich Mean Solar Time. 1894. | d | h | m | s | Observer. | ✓−✱ RA. m | s | Corr. for Refraction. s | Log. factor of Parallax. | ✓−✱ N.P.D. ′ | ″ | Corr. for Refraction. ″ | Log. factor of Parallax. ″ | No. of Comps. | Apparent R.A. h | m | s | Apparent N.P.D. ° | ′ | ″ | Comp. ✱ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| May | 1 | 8 | 47 | 8 | A. C. | −0 | 9·00 | −0·02 | 9·4850 | + 2 | 18·2 | +0·6 | 0·8765 | 2 | 7 | 53 | 42·97 | 105 | 24 | 25·6 | *a* |
| | 1 | 8 | 52 | 58 | B. | −0 | 5·62 | −0·02 | 9·4926 | + 1 | 14·0 | +0·4 | 0·8748 | 4 | 7 | 53 | 46·35 | 105 | 23 | 21·2 | *a* |
| | 4 | 8 | 42 | 29 | ,, | −0 | 9·11 | +0·01 | 9·4252 | − 1 | 55·5 | −0·1 | 0·8511 | 6 | | ... | | | ... | | *b* |
| | 7 | 9 | 4 | 32 | ,, | +0 | 5·93 | +0·02 | 9·4338 | −10 | 31·6 | −0·2 | 0·8030 | 7 | 8 | 57 | 43·35 | 82 | 35 | 28·4 | *c* |
| | 7 | 9 | 24 | 52 | ,, | +0 | 44·47 | −0·03 | 9·4661 | +15 | 44·5 | +0·4 | 0·8061 | 5 | 8 | 57 | 51·20 | 82 | 32 | 50·1 | *d* |
| | 9 | 10 | 8 | 45 | C. D. | +0 | 57·99 | 0·00 | 9·5200 | − 0 | 23·3 | 0·0 | 0·7845 | 8 | 9 | 15 | 0·53 | 76 | 37 | 23·7 | *e* |
| | 9 | 10 | 12 | 33 | A. C. | +0 | 59·59 | 0·00 | 9·5240 | − 0 | 48·1 | −0·1 | 0·7856 | 1 | 9 | 15 | 2·13 | 76 | 36 | 58·8 | *e* |
| | 10 | 9 | 0 | 5 | C. D. | −1 | 9·81 | 0·00 | 9·4170 | + 1 | 24·6 | +0·1 | 0·7428 | 4 | 9 | 22 | 23·88 | 74 | 11 | 17·8 | *f* |

*Notes.*

The observations are corrected for refraction, but not for parallax. They are also corrected for the error of inclination of the wires and for the motion of the comet.

May 7.—Stellar nucleus seen south of centre of nebulosity; slight elongation of latter towards N.

The initials A. C., B., C. D., are those of Mr. Crommelin, Mr. Bryant, and Mr. Davidson, respectively.

*Comparison Stars.*

| | Star's Name. | R.A. 1894·0. h | m | s | N.P.D. 1894·0. ° | ′ | ″ | Authority. |
|---|---|---|---|---|---|---|---|---|
| *a* | O.A. (S.), 7742 | 7 | 53 | 51·72 | 105 | 22 | 1·5 | Oeltz. Arg. (S.), and Schjellerup. |
| *b* | B.D. −3°, 2390 | 8 | 28 | 22·6 | 93 | 17·8 | | Bonn, Observations, Vol. viii. |
| *c* | W.B. VIII., 1423 | 8 | 57 | 36·58 | 82 | 45 | 59·7 | Glasgow, 1870, Paris and Göttingen Catalogues. |
| *d* | W.B. VIII., 1414 | 8 | 57 | 5·94 | 82 | 17 | 4·9 | Glasgow, 1870, Paris and Armagh, 1875, Catalogues. |
| *e* | W.B. IX., 235 | 9 | 14 | 1·58 | 76 | 37 | 48·1 | Paris Catalogue. |
| *f* | W.B. (2) IX., 450 | 9 | 23 | 32·65 | 74 | 9 | 54·7 | Weisse's Bessel (2). |

*Royal Observatory, Greenwich:* 1894 *May* 11.

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